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Surveyed were current objectives, teaching methods and teaching materials used in introductory college chemistry. Six general objectives were identified (1) to develop the ability to do critical thinking, (2) to make the students familiar with the facts, principles, and concepts of chemistry, (3) to help the students understand the nature of matter and its transformation, (4) to develop the ability to handle quantitative problems, (5) to develop intellectual honesty rather than foster the search for the "right" answer, and (6) to teach students to be precise in observation and expression. Data obtained indicated (1) the nature of the first year course is not clearly defined, (2) the introductory courses are in the midst of considerable revision, (3) modern teaching aids and materials recommended by the Advisory Council on College Chemistry are not being used, (4) some emphasis is placed on interdisciplinary cooperation, and (5) professional educators seem unclear about objectives and outcomes of introductory college chemistry courses. (GR)

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U S DEPARTMENT OF
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PREFACE

The observation is not new, neither is it unconfirmed by others, that there is a diversity of opinion as to what course content should be taught in introductory college chemistry, how it should be taught, and what materials should be used. The primary contention now seems to be to consolidate these diverse opinions and practices and attempt to ascertain some order out of the controversies and diversity.

A few investigations have been directed at determining the objectives of general college chemistry, the course content of introductory college chemistry, and motivation practices in first year college chemistry. These noteworthy attempts have been meager when compared to the prolific writing of chemistry educators describing the objectives and content of courses taught at their respective institutions of higher education. The Advisory Council on College Chemistry has described a course directed at the university level. The question is asked, "Do introductory college chemistry courses directed at the university meet with the needs of other institutions of higher learning, namely, the liberal arts colleges and the junior colleges?" The literature is abundant with articles showing a diversity of teaching practices but few solutions are offered.

Fully cognizant of the damage of oversimplification and distortion of meaning, an attempt will here be made to consolidate these previous

writings, suggestions, and research findings. This is in order to obtain a clear cut view of what current objectives, teaching methods, and materials are being used in the accredited colleges and universities.

ACKNOWLEDGEMENTS

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Finally, to my family and especially my wife, who each in his own manner contributed heartedly and unselfishly to the completion of the survey project, goes an expression of infinite thanks.

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PROBLEM AND OBJECTIVES

Statement of the Problem

The purpose of this survey is to determine the present objectives, teaching methods, and materials used in teaching the introductory course in college chemistry in selected accredited colleges and universities in the continental United States. The investigation is directed at current objectives, methods, and materials with respect to the various colleges and universities.

Procedure Used in the Study

The procedure used in the survey was an examination of the teaching practices used by instructors in the teaching of introductory college chemistry in selected accredited colleges and universities by means of a questionnaire.

Need for the Study

Many college professors are involved in extensive revision of their introductory college chemistry courses.[1] The revision activities are directed toward a redefinition of the scope of undergraduate chemistry

[1] Symposium, "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41 (1964), pp. 126-147.

training, toward a reformulation of the relationship between chemistry and related fields, and toward remodeling of new teaching materials and introduction of new concepts.[2] One consequence of these modifications is that no one knows just what the nature of the introductory college chemistry is at the present time.[3] There are no agreed upon standards of content for the introductory college chemistry course and, as a result, local evaluation is difficult.[4] Introductory college chemistry teachers must begin to think of essential objectives for chemistry and flexibility in evaluating whether or not those objectives are being achieved.[5]

The review of introductory college chemistry course revisions shows, in many cases, that the only clues to local and nationwide evaluation of the introductory college chemistry courses have been (1) the enthusiasm of professors about their own chemistry program and the transmission of this exhilaration to the students; (2) the number of students who have survived the ministrations; (3) the curricular changes that have proved stimulating to the professors; (4) the consensus of the staff and teaching assistants that the new changes are quite effective and deserve approbation; (5) the students' enjoyment in doing laboratory experiments and their appreciation for and respect of the expensive equipment used; and (6) the success of the course revision is judged upon the number of students entering chemistry as major fields or being prepared for other professional careers which incorporate chemistry as a supporting field.

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[2]Ibid., p. 126.

[3]Robert I. Walter, "The Changing Curriculum in Chemistry: Some Contemporary Developments," Journal of Chemical Education, 42 (1965), p. 524.

[4]Richard G. Yalman, "Chemistry in Liberal Arts Colleges," Journal of Chemical Education, 41 (1964) p. 145.

[5]Ibid., p. 144.

The statement of course objectives and the ensuing evaluation schemes are particularly individual ones in each college and university. Although the educational results obtained at one educational institution may not be comparable with the results that have been obtained at another institution, the findings from a survey and analysis of the teaching practices in introductory college chemistry in the presumption that they could indicate trends, could be of value to interested individuals and/or groups.

Scope and Limitations of the Survey

There are approximately 1,636 accredited institutions of higher education that offer introductory college chemistry, but the results of this study must be limited to the sample of 351 accredited colleges and universities in the continental United States.

The second limiting factor is that the sample for the survey was selected from only those colleges which grant chemistry credit in the first-year college chemistry course. The survey is concerned with a widely dispersed population; and, since many colleges and universities are involved and their courses vary in content and thoroughness, this investigation will be specific and directed at selected accredited colleges and universities. Any conclusions will be general only in so far as the same conditions pertain to other colleges as were present in the colleges studied.

Population of the Survey

The population for this study consists of 351 accredited institutions of higher education. The investigator found that several institutions have either replaced introductory college chemistry with a course in Science Fundamentals or have replaced it with a multidiversity science course. In some instances, the introductory college chemistry course has

become an integral part of a comprehensive physical science course. For the purpose of this survey, only courses in introductory college chemistry which specifically carry credit in chemistry were considered. Courses in the philosophy of science, fundamentals of science, and chemistry courses designed specifically for non-science majors are not included in the survey.

Definitions and Interpretations

The Critical Ratio (t-test) is a statistical measure used to determine whether a real difference exists in a particular trait between two comparable groups. It is obtained by dividing the difference between the means of the groups of those traits by the standard error of difference between the means.

The Standard Error of Difference Between the Means is obtained by dividing the standard deviation from the mean of the college enrollment by the square root of the number of colleges in a given strata.

The Stratified Random Sample is achieved whenever a population, such as the total number of colleges, is divided into subgroups and some kind of random sample is taken in each group.

Strata is the subgroup from which the random sample is drawn.

Stratification is the process of dividing the population into groups.

Method of Optimum Allocation is the allocation of sample size in the respective strata for a fixed total sample size when the sampling variance is minimum. If previous information is available for approximating both the size of the strata and the variances of the characteristics within the strata, it is possible to allocate sample units among the strata.

Optimum Allocation concerns the choice of the sample sizes in the respective strata. Optimum allocation states that the sample size in a

stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or in other words that the sampling fraction should be proportional to the standard deviation. The allocation of sample size in the respective strata is said to be optimum for a fixed total sample size when the sampling variance is minimum.

Trend may be considered as a general prevailing movement, changing in a specific and indicated direction, and thus reflecting a recognizable change of tendency or emphasis.

Accredited Institutions are those institutions of higher education in the continental United States that are accredited by the nation's six regional associations of schools and colleges as listed on page vii of the Accredited Institutions of Higher Education, September, 1967, American Council on Higher Education, Washington, D. C.

Introductory College Chemistry refers to the first-year college chemistry course which receives credit under the title "chemistry" and meets the prerequisite requirement for further chemistry courses in a college curriculum.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

This chapter contains ideas and information obtained from reviewing the literature--research and theoretical--relevant to the proposed study. Specifically, the investigator will principally show the diversity of opinion among the professional chemistry educators that have implicitly permeated the teaching of the first-year college chemistry course (the introductory college chemistry course) and the history of that diversity.

Although several investigations have been directed at determining the objectives of the introductory course in college chemistry,[6] several surveys have attempted to delineate the course content in introductory college chemistry;[7,8] and a few educators have attempted to describe motivation practices[9] in general college chemistry. According to the titles of articles and abstracts in the Journal of Chemical Education, Chemical Abstracts, Education Index, and Dissertation Abstracts, there have been no surveys published that combine the aforementioned investigations and

[6] Otto M. Smith, "Accepted Objectives in the Teaching of General College Chemistry," Journal of Chemical Education, 12 (1935) p. 182.

[7] H. J. Nechamkin, "The Course Content of General Chemistry," Journal of Chemical Education, 38 (1961) p. 255.

[8] Jay A. Young, "The Content of the First Course in College Chemistry," Journal of Chemical Education, 41 (1964) pp. 477-478.

[9] Robert K. Summerbell, "The Excitement of Experiment," Journal of Chemical Education, 41 (1964) p. 126.

the teaching practices used in the introductory college chemistry course. The findings and conclusions of these investigations have been meager when compared to the numerous writings of the professional chemistry educators either in their individual descriptions of their own respective chemistry curriculum or the expoundings of their own personal satisfaction or dissatisfaction in regard to course objectives and the ensuing criticisms in regard to their own course and/or student evaluation.[10] In general, these writings and survey findings are inherent of one common ingredient; they either show a controversy or express a diversity of opinion among the professors of chemistry. The diversity of opinion among the members of the chemistry profession as to selection of what course content should be taught in introductory college chemistry, how and in what sequence these concepts should be taught, and what supplementary materials should be used is not new; neither is it unconfirmed by others.[11] One major question which has emerged from the variation and diversity is, "Do introductory college chemistry courses designed at the university level meet the needs of other institutions of higher education, namely the liberal arts colleges?"[12] An answer to this question is imperative since the Advisory Council on College Chemistry has shown statistics that indicate a transfer of 25 percent of two-year college students to either universities or four-year institutions.[13] The current revision activities with resultant

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[10]"Recent Trends in Undergraduate Chemistry Curricula," p. 126.

[11]Edward L. Haenisch, ed., The Content of Introductory College Chemistry, Wabash College, Indiana: Advisory Council on College Chemistry, December, 1954, p. 5.

[12]Nelson McKain, Jr., "Rigor or Breadth for Freshmen," Chemical and Engineering News, 42, March 23, 1964, p. 4.

[13]Haenisch, p. 5.

emphasis on the individual practices and opinions of individual educators and/or individual institutions regarding the nature and characteristics of what these educators think the introductory college course should be have resulted in so many various and uncorrelated curricula changes. Some of the college educators believe that the revision activities are being redirected toward a redefinition of the scope of the undergraduate chemistry training, toward a reformulation between chemistry and related fields, and toward a remodeling of new teaching materials and the resulting introduction of new concepts.[14] Others feel that the consequence of these course modifications is such that no one really knows just what the nature of the introductory course in college chemistry is at present.[15] Furthermore, there are no agreed upon standards of content for the introductory college chemistry course and, as a result, local and/or national evaluation is difficult.[16] The investigator believes that the evidence warrants, in part characterization of the situation by saying that the professional chemistry educators do not know what they really want to do in introductory college chemistry.

Although first-year college chemistry courses have been described in the literature as ranging in content from largely descriptive to largely theoretical, the material presently being taught probably is determined by current textbooks. The point is that when defining just what is the basic content to introductory college chemistry, the inclusion of non-traditional topics which modern chemistry texts has incorporated makes formulating a curriculum extremely difficult. For example, should classical concepts

[14]"Recent Trends in Undergraduate Chemistry Curricula," pp. 126-147.

[15]Walter, p. 524.

[16]Yalman, p. 145.

be dropped in favor of a theoretical approach based on non-traditional topics and the like? Many industrial chemists say that today's bachelor degree chemist lack a good knowledge of descriptive chemistry.[17] What about descriptive chemistry and the amount of descriptive chemistry in general college chemistry?

The evaluation schemes previously described on pages two and three compound rather than alleviate the decision regarding the choice of content and method of presentation, whether it be descriptive, theoretical, or combination, by being too illusive and vague. A direct implication of some chemistry educators is that it is time the teaching profession began to think of essential objectives for chemistry and try to develop some specific methods in evaluating whether or not these stated objectives have been achieved.[18] The development of course practices has been so numerous and the differences of opinion so varied that the Advisory Council on College Chemistry (AC_3) has held conferences to study content of freshman chemistry courses. AC_3 has also been studying some of the other major problems confronting introductory college chemistry professors. The Council, at present, is seeking answers to the following questions:

(1) What science, if any, should be taught nonscience majors?
(2) What topics should be taught to chemistry majors?
(3) What new teaching aids, if any, will combat successfully the onslaught of increasing enrollments?
(4) Should freshman chemistry courses be redesigned along broad topical lines such as dynamics, structure, and synthesis?
(5) What is the future role of liberal arts colleges and junior colleges in chemical education?[19]

None of these questions has been fully answered, but some of the AC_3 Council members have expressed guarded optimism that partial answers are now available.

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[17]"Airline House: Airing Needs," Chemical Engineering News, 46, October 14, 1968, p. 48.

[18]Ibid., p. 144.

[19]"AC_3 Zeros in on Chemical Education," Chemical and Engineering News, August 1, 1966, pp. 40-41.

The present era is also characterized by a plea for an analysis of first-year college chemistry teaching practices.[20,21,22] In addition to aims and objectives, the teaching methods and materials used in the beginning college chemistry courses have been, and are, a matter of concern. Interestingly enough, however, the objective surveys in this field of investigation have been few, and these have been open to criticism.

Probably the only consistency in the replies to the question, "What are you doing in the first-year chemistry course?" is the universal dissatisfaction with what has been done and the variety in the proposals tried or planned in the near future.[23] Perhaps the present concern for an analysis of teaching practices as well as course objectives and evaluation emanates from the variety of programs being implemented at each individual university or college.

Historical Background

At the beginning of the nineteenth century, introductory college chemistry was taught by a combination of textbook readings and didactic instruction. Lectures on college chemistry in the United States were given at Amherst, Brown, Harvard, Rensselaer, West Point, and other colleges and universities.[24] A widely distributed textbook designed to

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[20] William C. Morgan, "Symposium: What Are Our Objectives Teaching Chemistry?" Journal of Chemical Education, 2 (1925) pp. 971-975.

[21] Yalman, p. 142.

[22] Laurence E. Strong, "College Chemistry--The Road to Nonsense or Science, "Chemical and Engineering News, 43, February 22, 1965, p. 128.

[23] "Editorially Speaking, "Journal of Chemical Education, 41 (1964) p. 115.

[24] Frederick Rudolph, The American College and University, New York: Vintage Books, 1962, pp. 222-223, 225, 227, 229-231.

accompany these lectures was edited by John M. Webster, Erving Professor of Chemistry and Mineralogy at Harvard. His lectures and textbooks were typical of the time and covered the entire range of chemical knowledge including Daton's atomic theory, laws of definite and multiple proportions, equivalent weights, the chemistry of the elements, organic, physiological and analytical chemistry.[25]

In the years following the Civil War, a force appeared on the American collegiate scene that revolutionized instruction of first-year college chemistry. The outgrowth of the return of a large number of American students from German universities caused a very noteworthy change--the introduction of laboratory work to accompany the lecture and the textbook.[26] The typical procedure which evolved was to teach first-year college chemistry by a combination of laboratory work, textbook and didactic instruction carried on simultaneously, with at least one half of the time devoted to laboratory work. Woodburn and Obourn[27] have characterized the textbooks of this post Civil War period to be organized around the logic of subject with practically no attention devoted to the psychology of learning.

Philosophically, there was evidence early in the post Civil War period indicate that a few educators were shifting from the theoretical and factual method of teaching to the inductive or experimental method of teaching. Evidence of this trend was found in the preface of the Elementary Manual of Chemistry, 1872, by Eliot and Storer. They favored the experimental and inductive method to teaching chemistry when they wrote:

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[25]Yalman, p. 142.

[26]J. O. Frank, The Teaching of High School Chemistry, Oshkosh, Wisconsin: J. O. Franks and Sons, 1932, p. 8.

[27]John Woodburn and Ellsworth S. Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 194.

> The authors object is to facilitate the learning of chemistry by the experimental and inductive method, to develop and discipline the observing faculties.[28]

Later, Storer and Lindsley reinforced the view that chemistry should be taught by the experimental and inductive method by stating:

> The student acquaints himself with facts and principles through attentive use of his own perceptive faculties.[29]

The emphasis on the experimental method of teaching was soon to change, however. Toward the end of the last decade of the nineteenth century, there were some evidences of a general distrust of the inductive method as shown in the forthcoming comments of Carhart and Chute when they wrote:

> A few years ago it seemed necessary to urge upon teachers the adoption of laboratory methods to illustrate the textbooks; in a few instances it would seem almost necessary to urge the use of a textbook to render intelligible the chaotic work of the laboratory.....the pupil should be kept in his classwork well ahead of the subjects forming the basis of his laboratory experiments.[30]

A Survey of the History of the Controversy in Introductory College Chemistry

This ensuing controversy over the laboratory objectives and the sequence order of experiments when placed in juxtaposition with textbook content appears to have set the stage for a controversy regarding differences in opinion over course objectives and course content. An objective appraisal

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[28]Eliot and Storer, in Woodburn and Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 192.

[29]Storer and Lindsley in J. D. Steele, Fourteen Weeks in Chemistry. New York: A. S. Barnes and Company, 1873.

[30]Carhart and Chute, in Woodburn and Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 193.

of the period from 1872-1900 would have to acknowledge a genuine attempt to upgrade the teaching of chemistry through the improvement of laboratory work. This circumscribing thought, coupled with the cited charge of Woodburn and Obourn[31] that the introductory college curriculum in the closing years of the last decade of the nineteenth century had resulted in authoritarian teaching by deductive methods, probably is indicative of a new era in the psychological and pedagogical position as to the teaching of introductory college chemistry. This trend is also further exemplified by Yalman's assertion that chemical education, around 1910, was following classical lines; i.e., as the body of knowledge increased, systematic branches of chemistry appeared and so did the proliferation of chemistry courses.[32]

Prior to and succeeding World War I, forces began to emerge which caused the chemistry professors to shift their chemistry offerings to meet new demands. According to Merwin,[33] these influential forces were the seven cardinal principles of secondary education, 1918,[34] the final report of the Committee on Sciences of the Commission on the Reorganization of Secondary Education, 1920,[35] and Frederick J. Kelley's study of the liberal arts colleges.[36] The Seven Cardinal Principles listed objectives of

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[31]Woodburn and Obourn, p. 194.

[32]Yalman, p. 143.

[33]B.W. Merwin, "Development of the Curriculum in College Chemistry," Journal of Chemical Education. 12 (1935), p. 543.

[34]Cardinal Principles of Secondary Education. Bulletin No. 35. Washington: Department of Interior, Bureau of Education, 1918.

[35]Otis W. Caldwell and Committee, Report of the Subcommittee on the Teaching of Science, Bulletin No. 26. Washington: U. S. Bureau of Education, 1920, pp. 12-13.

[36]Yalman, p. 143.

education and the Committee on Sciences endorsed and recommended general chemistry for various curricula. Kelley's study called attention to the need for definite aims and made some suggestions, which in some cases, at least, appear to have stimulated and served as guides for the selection of additional courses in freshman chemistry. The combined influences of these forces produced a strong shift to the practical, the useful, in all school subjects; and an attempt was made to offer those subjects that will best fit the student for life in his community. First-year college chemistry courses and specialized chemistry courses were recommended for various curricula such as household chemistry and industrial chemistry. The first-year college chemistry course, as a result of these forces, was considerably modified. The time devoted to laboratory was lessened and the time allotted for demonstration work was increased, while the disciplinary aim became the preparation of a student for life in the community in which he lived.[37] Professors directed their attention to pressing problems which were the results of the forces mentioned above compounded with the interest of a few to retain the inductive methodology. One of the most controversial areas, at that time, was the subject of correlation of high school and college chemistry. The criticisms became so numerous that the American Chemical Society appointed a Committee on Chemical Education to study the correlation of high school and college chemistry. In addition, another controversy developed from the issues resulting from pedagogical practices in laboratory work--the individual laboratory versus the demonstration laboratory.[38] In spite of these ramifications, the plea for objectives did not subside.

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[37]Ibid.

[38]R. L. Cooke, "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15 (1938) p. 592.

Objectives of General Chemistry

One of the most controversial areas of conflict among the chemistry educators is concerned with objectives, both local and national. Chemistry professors have always had objectives in chemical education, whether good or bad. These objectives are stated in textbooks, syllabi, curriculum guides, symposia, and suggestions of the Advisory Council on College Chemistry. The general objectives usually include statements to the effect that the student is to gain an understanding of the fundamental concepts of chemistry; the student is to increase in the ability to think critically; and the student is to understand relations between chemistry and society. These objectives sound good, but do they really provide a direction to what students need to do? Objectives need more specific outcomes. "To gain an understanding of the fundamental concepts of chemistry" is much too vague. Objectives should imply teaching processes and methods of evaluation.[39] The evidence is far from conclusive that chemical educators have alluded to any ground rules or frame of reference when discussing or making pleas for course objectives. Perhaps the renewed concern for objectives, as well as aims, emanated from the controversy over correlation of course content and the selection of laboratory methods. The growing concern for establishing specific objectives in general college chemistry was reflected by William C. Morgan, in 1925, in his introductory speech to a symposium entitled, "What Are Our Objectives in Teaching Chemistry?" Morgan further exemplified the controversy and literally took the college chemistry teacher to task by stating:

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[39]Earl T. Montaque and David P. Butts, "Behavioral Objectives," The Science Teacher, 35, March, 1968, pp. 33-35.

> John Dewey, one of the greatest educators the world has ever produced, has repeatedly stated that science offers nothing so valuable to mankind as a knowledge and appreciation of the scientific method. In one of the most significant books that have been published in recent years, James Harvey Robinson maintains that rational thinking (or the scientific method) has contributed more to the advancement of mankind than all other human efforts put together, and that nothing is now so important in education as a knowledge of its past accomplishments and future possibilities. Yet in the report of "A Standard Minimum High-School Course in Chemistry" there is no mention of the scientific method. Apparently, "a prophet is not without honor save in his own country."[40]

In his concluding remarks, Morgan issued the following challenge:

> What are we trying to do in teaching chemistry? Shall we endeavor to make of the minds of our students depositories of information in which the moth of forgetfulness and the rust of disuse will corrupt the facts? Shall we not teach them rather to know books and use libraries which will in time of need furnish them with exact information in a thousand-fold greater abundance than any one mind can comprehend? Shall we not strive to develop mental laboratories and teach the use of their equipment so that every last one of our students may realize the value of evidence and to some extent how to obtain it?[41]

The same year, C. H. Desch also expressed a similar view of the purpose of general chemistry when he remarked:

> Chemistry is an experimental science which progresses by the application of a definite discipline, obtaining conclusions by induction from the observed facts and making use of deduction from a small number of well-tried hypotheses where required.[42]

Apparently, two more prophets were without honor in their own countries. Other professors tried to redirect chemical educators back to a statement of objectives. The emphasis had shifted away from course objectives to the subjects of correlation of high school and college chemistry and the content of general college chemistry, the controversy regarding the

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[40]Morgan, p. 971.

[41]Ibid., p. 975.

[42]C. H. Desch, "The Discipline of Chemistry," Nature, 116 (1925) pp. 504-505.

contributions of high school chemistry toward success in the college chemistry course, and the debate on which method of laboratory instruction is needed in introductory college chemistry. An attempt was made by W. A. Noyes, Jr., to consolidate objectives and course content when he expressed concern for the quality of the chemistry graduate by writing:

> The lack of properly trained chemists is due to first, the scheme of training, second, to the type of teacher too commonly found in our colleges and finally, the low and uncertain standards of a large number of our schools. ...More objective standards are needed that they may be more uniformly applied throughout our systems of colleges.[43]

The neglect of course objectives was only transient, however. Otto M. Smith, Oklahoma State University, 1935, redirected the chemistry educators back to the importance of course objectives when he wrote:

> It was felt that the desirable content of general chemistry was sufficiently covered by the Committee on the Correlation of High-School and College Chemistry in their list of topics for a minimum high-school course in chemistry. The attention of the committee was directed toward other objectives, in reality more important. It was thought that it is not primarily the mastery of the subject matter but the ability to meet situations and to solve them that constitutes the more valuable training the student receives.[44]

Smith supplied a questionnaire which contained a preselected list of proposed objectives to be rated according to a scale ranging from "most important" or "an essential aim" to "incorrect, not an aim under any condition." This research was an attempt to classify the accepted objectives under the seven cardinal principles of secondary education. Considering a return of sixty-six percent to indicate the proposed objective to be generally accepted as such, Smith's findings were summarized as follows:

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[43]W. A. Noyes, Jr., "Training the Chemist--A Critical Survey," Chemistry Bulletin, 12 (1925) pp. 67-68.

[44]Smith, pp. 180-183.

(I) A study of chemistry should provide the individual with a broad and genuine appreciation and understanding of the chemical aspects of the universe; of the place of chemistry among the sciences; and of what the developments in chemistry mean in modern social and industrial life (good citizenship).

(II) A study of chemistry should provide an opportunity for the acquisition: of experiences in the use and the knowledge of the scientific method of thinking, using chemical problems; of a knowledge of natural laws, important principles and facts; of the ability to draw and to apply important principles; and of some skill in laboratory manipulation.

(III) A study of chemistry should provide an opportunity for the individual to determine his interests and aptitudes in chemistry as a vocation.[45]

The need for delineation of purposes of instruction in introductory college chemistry was recognized in 1941 by the Committee on the Improvement of Science Instruction for purposes of General Education, a special committee of the American Association for the Advancement of Science on the Improvement of Science Teaching in Colleges and Universities, when L. W. Taylor, chairman of the committee, advanced the following statement:

> A relatively small number of the students who enter the introductory course in college chemistry continue their study in more advanced courses. A larger group of students take the course in order to meet certain requirements and still another group take the course solely for its contribution to their general education. The assumption has usually been made that essentially the same type of intorductory chemistry course meets the needs of these different groups of students. One of the questions of general concern which this committee believes should be studied may be phrased as follows: Does the conventional introductory college course in chemistry through its content and method of instruction make a larger contribution to the education of those students who do not continue the study of the subject than would be possible in a different type of course?[46]

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[45] Ibid.

[46] L. W. Taylor, Chairman, et. al., "Chemistry Instruction for Purposes of General Education," Journal of Chemical Education, 18 (1941) p. 11.

A questionnaire was sent to approximately 500 colleges and universities to ascertain the purposes of instruction in introductory college chemistry courses designed for non-science majors. The survey findings gave sufficient evidence to suggest a separate introductory chemistry course for non-science majors. The survey findings also reflected the point of view that the majority of those professors who teach an introductory course designed for both science majors and non-science majors feel that this course is, in general, unsatisfactory for the non-specialized student. The respondents believed that this regular course could be significantly improved for the non-specialized student, but they also expressed the fear that modification of the regular course may lead to superficial results for the specializing student. Instructors felt that an additional general chemistry course should be offered, but not the type commonly known as a physical science survey.

B. Clifford Hendricks, University of Nebraska, in 1942, concurred with the findings of Taylor; but he voiced strong opposition to some of the objectives listed in the survey findings of smith when he presented the following argument:

> Some time ago a set of objectives was compiled which was approved by a representative group of college teachers of chemistry. This approval was probably given in the hope that such objectives, when achieved, would lead to successful work on the parts of students in subsequent courses.
>
> Such an assumption, that success in one course is indicated by a good record in a subsequent one, is erroneous in two particulars. It overlooks the fact that probably more than fifty percent of those students in service courses will never take any more chemistry and second, it assumes the doubtful inference that the greatest good to this group of students comes from remembering the understanding the technical intricacies of general chemistry. It is with this second assumption that professional schools take issue.[47]

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[47]B. Clifford Hendricks, University of Nebraska, "The Varied Objectives in Service Courses in General Chemistry, "Journal of Chemical Education, 19 (1942) pp. 265-266.

This controversy was further extended by Hendricks' assertion that professional schools are really quite serious in their endeavor to have chemistry taught their students which will contribute to professional success rather than to high attainment in pure chemistry. Among the inferences of the preceding comments, the present investigator detected the Hendricks notion that one introductory college chemistry course was not sufficient.

A subjective but comprehensive description of the objectives of general chemistry and an indirect suggestive implication of agreement with Hendricks was vividly voiced by Hubert N. Alyea, Princeton University:

> We are chemists by profession because we are experimentalists by nature, and because some years ago we were students, our chemistry teachers wisely encouraged us in experimental research and we liked it.
>
> It is our duty, in turn, to imbue the next generation of young men with the understanding and spirit of research; and that, I believe, is the prime junction of the general chemistry course.[48]

Alyea characterized research as being composed of three integral parts: (1) curiosity (2) fact finding and the acquisition of knowledge and (3) critical judgment. In summation, Alyea explained the function of introductory college chemistry:

> The relative emphasis on these three items depends naturally upon the particular course and its relation to the subsequent programs of the student. By electing the advanced general chemistry courses, the student has already indicated his scientific bent and his stimulated curiosity so that a fundamental training in advanced inorganic chemistry and the exercising of sound judgment is prescribed. On the other hand, for the beginner who will probably not continue in chemistry, curiosity and judgment are paramount, while knowledge is merely of transient importance.[49]

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[48]Hubert N. Alyea, "The Function of General Chemistry," Journal of Chemical Education, 18 (1942) pp. 309-310.

[49]Ibid., p. 310.

C. S. Adams, Antioch College, 1943, in reviewing the literature of laboratory objectives, developed a reservation regarding lack of research by college professors in regard to laboratory objectives and pedagogical practices. He showed that out of fifty literature references related to methods of laboratory instruction, covering a period of over thirty years, only five were applied to college classes.[50] The results of Adams' questionnaire and a similar study by Leonard F. Sheerer indicated the acceptance of the following as the objectives of general college chemistry laboratory work:

(a) develop the ability to make observations, interpret and draw conclusions from observed facts,
(b) develop the ability to use simple scientific instruments and manipulate apparatus,
(c) develop the ability to keep or record and write a satisfactory report,
(d) develop the attitude of drawing conclusions only from observable or acceptable data,
(e) develop the habits of accuracy, honesty, self-reliance, cleanliness, and orderliness in laboratory,
(f) satisfy the student's curiosity and provide experience to develop latent interests,
(g) provide opportunity for instruction.[51]

The results of Adams' questionnaire gave ample truth that the teachers of general college chemistry were interested in new and improved testing devices, particularly as these related to laboratory achievement. Adams succinctly stated the status of the laboratory objectives in 1943 when he wrote:

> Very little progress has been made in developing adequate devices for measuring the achievement of the accepted objectives of laboratory work in general chemistry, other

[50] C. S. Adams, "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20 (1943) pp. 266-270.

[51] Leonard F. Sheerer, in Adams, "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20 (1943) p. 266.

than the acquisition of knowledge. The paper-and-pencil measures of chemistry laboratory achievement that have thus far been devised fail to show consistent or marked differences among the several methods of laboratory instruction.

Performance tests, such as those reported by E. O. Smith and his staff, have produced encouraging results in measuring some of the laboratory objectives. Other studies are needed, particularly on the part of larger colleges and universities, in order to obtain statistically significant results so important in investigations of this kind.[52]

A survey of the literature since 1943 shows only a few articles directed toward objectives and/or evaluation. The collective and annual indices of the Journal of Chemical Education, with few exceptions, has deleted the references and cross references to objectives, namely the words objectives, aims, and collateral values. Nevertheless, many individuals, in discussing their respective chemistry curricula, have emphasized the need for both local and nationwide objectives. Jay A. Young reinforced Adams' request by offering constructive assistance when he formulated a new set of laboratory objectives.[53] Young is of the opinion that the laboratory objectives currently found in the prefaces of many lab manuals are of limited value. The criteria offered by Young, in reality, are modifications of the old objectives stated in behavioral terms in such a manner as to enhance and sharpen thinking. His opinions of the purposes of the laboratory and the ensuing criterion is not unlike the behavioral objectives of Montaque and Butts described on page 15. Indirectly, L. K. Nash[54] and the Advisory Council on College Chemistry[55] have implied the

[52]Ibid., p. 269.

[53]Jay A. Young, "The Educational Use of Data—Challenge in the Laboratory," Journal of Chemical Education, 41 (1966) pp. 120-123.

[54]L. K. Nash, "Boundary Conditions," Journal of Chemical Education, 41 (1964) p. 368.

[55]Haenisch, pp. 2-3.

need for objectives and methods of evaluation in their criteria for inclusion of a topic in introductory college chemistry described on pages 35 and 36.

At present, there are almost as many sets of objectives as there are chemists interested in the freshman course;[56] however, several objectives, both for science and nonscience majors keep appearing in various forms, They are:

(1) Enthusiasm and interest in chemistry as an experimental science should be aroused by making the work intellectually stimulating and allowing the student to enjoy the laboratory experience within the limits imposed by safety considerations.
(2) The student should realize the nature of chemistry as an experimental science, concerned with trying to describe accurately what is happening when changes occur and then explain how and why these changes take place.
(3) There should be a maximum development in each student of his powers of observation and reason. He should understand and feel he is a part of the procedure of observation, generalization, and verification.
(4) The chemistry major, in particular, should acquire knowledge of certain techniques and manual facility in handling some scientific instruments.
(5) The laboratory should illustrate and reinforce the lecture.[57]

A few moments of deliberation give one the feeling that he is in a time machine which is operating in reverse. These objectives appear to be the reworded phrases of Adams and Sheerer referred to on page 20. The inherent problem, therefore, does not appear to be a statement of purposes but a development of teaching procedures to meet these goals.

The Content of Introductory College Chemistry

Apparently, the forces that were responsible for the unanimity of opinion regarding introductory college chemistry course objectives during

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[56] Ibid., p. 18.

[57] Ibid.

the period 1918-1943 also contributed to a parallel controversy in regard to course content and the choice and sequence of topics. Although, in 1941, there was more or less consensus regarding topics to be covered in a first-year college chemistry course, the sequence of topics was a problem which required some thought before a definite plan could be formulated. Valuable assistance was offered by Joseph A. Babor, College of the City of New York, in 1942, when he listed the following selection guidelines to a choice of topics for inclusion in a general chemistry course:

> (1) What is the objective of the course in general chemistry in a particular college?
> (2) Another consideration which should influence the choice and sequence of topics is the previous preparation of the student.
> (3) The course may be designed to meet the requirements of two groups of students: those who intend to go on in chemistry and those who do not.[58]

Babor felt that a course based on criteria (2) above must be organized in such a manner that the choice and sequence of topics will provide basic principles, applications and sufficient theory to satisfy a chemistry major and not too much to discourage the art student.

Horace G. Deming, in 1948, issued a challenge to fellow educators by suggesting a pedagogical maneuver to challenge the voluminous increase in content and the resulting increase in size of textbook by remarking:

> It is better to treat a few topics in such a manner that students learn to think rather than range over many topics in a superficial way..... So the way to future progress seems to lie in more thought on the part of college instructors about goals and purposes.[59]

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[58]Joseph A. Babor, "The Sequence of Topics in General Chemistry," Journal of Chemical Education, 19 (1940) pp. 263-264.

[59]Horace G. Deming, "Guinea Pigs in the Classroom," Journal of Chemical Education, 25 (1948) pp. 445-449.

In reinforcing the views of Deming and also in answering the question, "What shall we leave out of general chemistry courses?" J. A. Shotton advocated a negative approach to the topic selection criteria of Babor and gave the following conslusions which were the results of a general chemistry workshop:

> No general agreement was reached, but the following criteria to aid a teacher in deciding what he should leave out were evolved:
> (1) can the ideas be taught and learned?
> (2) are we teaching content or methods of chemistry?
> (3) are they needed to keep the course accredited?
> (4) are they needed as professional training?
> (5) are they of local importance?
> (6) are they needed for everyday living?[60]

The workshop showed that the controversy is further exemplofied by the other problems of general chemistry. These were and still are (1) why is it difficult to obtain agreement on what is fundamental? (2) how many general chemistry courses must we teach? (3) do students have difficulty with the concept of chemistry because of difficulty with arithmetic, or not being able to derive the correct mental picture? Implicitly permeating the statements of goals and objectives of the post World War II era is the demand for critical thinking. Deming and Shotton were of the opinion that the general objective of chemistry is to encourage the student to think critically.

Admitting conjecture in part, Karol J. Mysels and Charles S. Copeland,[61] University of South Carolina, surmised that the overall content of a beginning course in college chemistry is rather well defined by the required

[60]J. A. Shotton, "A General Chemistry Workshop," Journal of Chemical Education, 27 (1950) pp. 619-621.

[61]Karol J. Mysels and Charles S. Copeland, "The Sequence of Topics in a Beginners' Course," Journal of Chemical Education, 28 (1951) pp. 163-167.

or traditional curriculum and generally accepted as such; the point of contention being that the point of view of the instructor is reflected in the sequence in which topics are presented and the approach that is used in the topic presentation. These authors were of the opinion that this is an inherent pedagogical weakness which could be strengthened by a careful selection of sequence of topics. Their criteria for inclusion of a topic in freshman chemistry, different in point of view from that of Babor, was offered partitively:

> The ultimate goal would be for the student not to depend upon the instructor's work except for a limited number of statements of fact. To approach this goal it is necessary to proceed from the simple and familiar to the more complicated and less familiar. This tends to give the student a continuous grasp of the material and allows him to follow the reasoning better at each step. There is also a general extension of the range of phenomena directly observable by means within the students grasp. In other words, a good basis should be firmly laid at each point before proceeding to the next. Finally, we feel that related phenomena should be grouped together, both for each of learning and as an illustration of the generality of the principle involved.[62]

Philip J. Elving offered a somewhat different view than that of Babor and Mysels, when he expressed the opinion that the order in which descriptive topics are introduced varies greatly and is perhaps immaterial so long as some logical pattern is followed. Elving also felt that the amount of time that is devoted to the various descriptive topics should be an individual professor choice which is directly dependent upon teacher and student interest.[63]

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[62]Ibid., p. 167.

[63]Philip J. Elving, "The Curriculum in Chemistry," Journal of Chemical Education, 29 (1952) p. 219.

John E. Cavelti,[64] Allegheny College, in 1943, supported a somewhat different approach than previous writers when he not only discussed the selection of content but gave specific examples to support his suggestions. Cavelti was convinced that the first need is a careful consideration of the content of the courses in the chemistry curriculum, correlated with a view to simplification, with an emphasis on fundamentals in each course, and a real integration of courses so that the graduate will not only be familiar with developments in all important fields, but will also be confidently grounded in the fundamentals of science. Cavelti advocated a structural method for selecting course content by stating the following points:

> Decisions as to the proper content of an elementary course are always difficult, and especially so in smaller institutions, where, of necessity, students with different aims must be taught together. Obviously, those things must be included which the student who will take no further courses in chemistry may reasonably be expected to need to know. For this reason the modern tendency to include a sketch of organic chemistry seems thoroughly desirable, although in courses intended specifically for chemistry majors it might well be omitted. For these students the real aim of the course should, it seems to me, be such a grounding in the fundamental theories and facts that the resulting knowledge can be relied upon to be there when we wish to build upon it in more advanced courses. I think most of us will agree that the basis of the course should be an exposition of the facts of the atomic structure, rather than of the methods by which they were obtained, and the application of these facts, through the periodic system, to the chemical behavior of elements and compounds. We are fortunate, in chemistry, to have so powerful a coordinating mechanism. In this regard the newer developments have simplified our task rather than complicated it.[65]

Cavelti, without any corresponding agreement as to topics which may be omitted, suggested the following content topics, which seem to be in

[64]John E. Cavelti, "The Perennial Problem of Course Content in a Growing Science," Journal of Chemical Education, 20 (1943) pp. 271-273.

[65]Ibid., p. 272.

contrast to the above quotation, tantamount to achieving his previously stated objectives: (1) the balancing of oxidation-reduction equations, except in the case of the simplest direct electron-transfer types; (2) complicated examples of chemical equilibria, solubility products, and the like; (3) calculations involving the normality concept; (4) all except brief reference, with no expectation of retention, to such topics as the application of X-rays to the determination of crystal structures, radioactive degradation series, methods of determining molecular weights (except direct applications of Avogadro's law, and perhaps freezing point depression), colloid chemistry, the meaning of electrode potentials, etc.

Cavelti surmised that there is a need for an elementary course which is elementary, but intense, and which stresses descriptive inorganic chemistry to a greater extent than is now customary. Norman Davidson projected another criteria for inclusion and selection of content for the introductory college chemistry course.[66] Davidson advocated lectures on special topics where one can illustrate the utility of structural considerations in explaining the properties of substances. To Davidson, the important thing is not just what or how many facts we teach, but that we stimulate our students to have a healthy interest in facts. He believes that this objective, the intelligent use of facts, could be effectively achieved by subjecting the student to an extensive study of selected topics in descriptive chemistry, correlated by constant references to actual experimental material and interpreted temporally with theoretical material. In summary, Davidson remarked:

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[66]Norman Davidson, "Theoretical Chemistry and Descriptive Chemistry in the General Chemistry Course," Journal of Chemical Education, 27, (1950) pp. 445-447.

> Then, I think that in spite of an ever-increasing amount of factual information, chemistry is not becoming more and more fragmented. It is becoming more and more integrated and unified by general theories and by general methods of investigation which are applicable to a variety of fields... To participate in this synthesis, the student must have training in both descriptive and theoretical chemistry, and I believe there will be greater emphasis on the correlation of descriptive and theoretical topics.[67]

Arnold J. Currier, Pennsylvania State University, in 1955, discussed a difficult problem in the teaching of general chemistry which resulted from the dual viewpoint in connection with the use of a textbook correlated with the laboratory manual.[68] This personal preference is to place more emphasis upon the textbook material. In defense of his stated preference for textbook material, Currier explains:

> In all too many cases, the student gets the impression that the experimental work is largely a matter of illustration or confirmation of the material presented in the textbook. To a large degree this aspect of the laboratory work may be a desirable one, but the thoughtful and perhaps less ambitious student can rightfully say, "What's the use of doing the experimental work when we know the answers because they are all in the book?" Some of the laboratory manuals of the workbook type which include exercises involving the tabulation of facts or data from the textbooks may be especially conducive to this point of view.
>
> To correct this undesirable tendency or practice, some writers have prepared texts which make the individual experimental work the focal point of the course.[69]

In 1958, Laurence E. Strong and O. Theodore Benfey gave a conflicting view to that of Davidson regarding the surfeit of knowledge when they discerned the trend regarding chemical concepts at the freshman level by inferring:

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[67] Ibid., p. 447.

[68] Arnold J. Currier, "Trends in Chemical Education," Journal of Chemical Education, 37, (1955) pp. 286-289

[69] Ibid., p. 289.

It is clear to the authors that there is a rife among chemistry teachers, a great amount of dissatisfaction with the present chemistry curriculum. On the other hand, there has been, to our knowledge, very little experimentation with major aspects of the teaching plan.

The Brown curriculum is a notable exception achieving remarkable success by dropping general chemistry and making essentially a simple rearrangement of the present courses, with organic chemistry as the freshman course.[70]

The Journal of Chemical Education described some thirty or more curriculum developments during the period 1957-1963.[71,72,73] Bennett R. Williford, Jr., at the Bucknell conference, Bucknell, Pennsylvania, reinforced the initial statement by Strong and Benfey and disagreed with the last statement when he reiterated the status of the content of introductory college chemistry vividly and succinctly, by concluding:

> There was no general agreement as to what constitutes the best freshman course. The majority favored a modernized course but few schools now find it best to begin with organic chemistry or an integrated-physics.[74]

Dating from the Brown experiment in 1958, the Journal of Chemical Education[75,76,77] and the Advisory Council on College Chemistry (AC_3)[78,79]

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[70]Laurence E. Strong and O. Theodore Benfey, "Chemical Concepts and the Chemistry Curriculum," Journal of Chemical Education, 35 (1958) p. 164.

[71]Bennett R. Williford, Jr., "The Undergraduate Training of Chemistry Majors," Journal of Chemical Education, 38 (1961) p. 251.

[72]Stephen E. Wiberly and Herbert H. Richtol, "A New Freshman Chemistry Program," Journal of Chemical Education, 41 (1964) p. 147.

[73]Walter, p. 524.

[74]Williford, p. 251.

[75]Journal of Chemical Education, 35 (1958) p. 164 ff., pp. 168-173.

[76]"Recent Trends in Undergraduate Chemistry Curricula," pp. 126-147.

[77]Journal of Chemical Education, 42 (1965) pp. 524-528.

[78]"Experimental Curricula in Chemistry."

[79]Haenisch, p. 5.

have either summarized or published numerous articles on introductory college chemistry courses which were designed for individual colleges and universities. These descriptions vary from independent study courses, to new laboratory courses, on to physics-chemistry combinations. The content ranges from a low level of difficulty to that which necessitates a good background in calculus for comprehension. The many forces or factors which are causing reconsideration of the content of the first college chemistry courses are well known.[80,81] One of the causes behind the revolution is the vast amount of chemical information and new theories that has been created in the past decade; hence, the new innovations in the first-year college chemistry courses contain new content. The literature survey shows some other modification agents, in general, to be: (1) freshman students are better prepared; (2) a wider variety of students, with diverse goals, abilities and backgrounds require closer consideration of specific needs of selected groups of students; (3) the flood of new information requires careful consideration of which topics are to be included in a course; (4) modern equipment makes available challenging new experiments for freshman laboratory as well as methods of presentation; and (5) availability of undergraduate grants from several federal agencies. Stephen E. Wiberly and Herbert H. Richtol, in 1964, were in agreement with the above factors that have caused changes in first-year chemistry curricula and, in addition, added a few when they gave the following reflection:

> Recent improvements in the teaching of high school chemistry and the advent of general chemistry texts with a change in emphasis plus the availability of undergraduate grants from

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[80]L. Carroll King, in "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41 (1964) p. 126.

[81]Haenisch, p. 3.

the National Science Foundation have brought changes in many first-year college chemistry courses.[82]

Individual professors, aware of the curriculum changes, began to call for assistance. Robert I. Walter, in discussing the survey report on the changing curriculum in chemistry, asked cooperation of his colleagues in the task of keeping a periodic check on evolving curricula by stating:

> It seems clear that exchange of information on changes in the curriculum are of value to schools which plan (or have already made) such changes. The experiences of others form a useful basis for one's own plans.[83]

Laurence Strong extended Walter's plea for cooperation by suggesting that interest should be initiated at the beginning level in college chemistry. Strong's statement testifies to the scope and influence of the content revolution at the college level when he stated: "If chemistry teaching is to become more effective, we need reorganized texts and courses."[84]

In view of the need to stimulate improved college chemistry teaching, the Advisory Council on College Chemistry (AC_3)[85] (an independent group of professors operating under a National Science Foundation Grant in an advisory capacity) appointed a Committee on General Chemistry in 1963. AC3 came into being as a result of an ad-hoc committee convened in October, 1961. This group was asked to consider the improvement of college chemistry teaching, especially in view of the Chemical Education Material Study

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[82]Wiberly and Richtol, p. 147.

[83]Walter, p. 524.

[84]Strong, p. 128.

[85]"Advisory Council on Chemistry Set Up," Chemical and Engineering News, January 14, 1963, pp. 43-44.

(CHEMS) and Chemical Bond Approach (CBA) programs at the secondary level and the great changes in the allied fields of biology, mathematics, and physics.

According to AC_3,[86] the content of the first-year chemistry courses in colleges and universities in the United States is generally determined by the available textbooks. AC_3 panel members concur that the principal way to improve the topics in college chemistry is to improve the textbooks and other teaching materials.

From the emphasis on content in terms of selected topics, chemistry professors are subsequently faced with delineating a core of topics. The concomitant activities and changes in introductory chemistry curricula have been labelled by King as "change".[87] J.A. Young's statement testifies to the scope and influence of the revolution (objective appraisal of the post World War II to 1964 period):

> It is well known that the selected topics being taught in introductory chemistry have changed during the past several years, particularly since 1946, but the usual sources of information concerning the details have been casually by word of mouth or informal conversations.[88]

AC_3 reinforced and confirmed the view of Young when the committee on General Chemistry remarked:

> There is considerable interest in delineating the hard core of topics presently being taught in introductory college chemistry. Many institutions are questioning the place of the first course within the total chemistry curriculum. The extent of adoption of new topics into introductory chemistry has not been known, although it is well known

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[86]L. Carroll King, "Modern Texts are Needed to Upgrade College Chemistry Courses; Freshmen Often Ready for Quantum Chemistry, Thermodynamics," Chemical and Engineering News, February 14, 1964, pp. 42-44.

[87]King, in "Recent Trends in Undergraduate College Chemistry," p. 126.

[88]Young, "The Content of the First Course in College Chemistry," p. 47.

> that there has been considerable change in course content in recent years. Teachers in junior colleges are particularly interested in knowing the main topics presented in introductory courses as taught in universities and four-year colleges. Currently, 25% of all undergraduates are studying in junior colleges, and many of these students later transfer to universities and four-year colleges. Core topics must be identified and taught to this large group of students if the transfer students are not to be put at a great disadvantage.[89]

Two surveys have been made heretofore to determine what topics have been taught and which are excluded in the first-year course. H. J. Nechamkin, in 1961, furnished a preselected list of topics to be rated according to a scale ranging from "essential for inclusion" to "unnecessary and should be omitted" in a questionnaire to which approximately 100 respondents replied.[90] A less subjective source of information on the content topics presently being taught in first-year college chemistry was undertaken by Jay A. Young.[91] The survey was sponsored by AC_3, and letters were sent to 100 randomly selected colleges, universities, and junior colleges requesting copies of the final examinations in the first-year chemistry courses for the academic year 1962-63. The primary purpose of the study was to find what topics are normally included in a general chemistry course, what changes are needed, and to stimulate improvement; that is, to provide useful information from which a sound basis for individually determined improvements could be established. A total of 52 institutions contributed final examinations for this study. Young observed that the general pattern of final examination topics closely followed the pattern of topics found

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[89] Haenisch, p. 5.

[90] King, in "Recent Trends in Undergraduate College Chemistry," p. 126.

[91] Young, "The Content of the First Course in College Chemistry," p. 477.

in available texts and, in conclusion, exclaimed: "It is, therefore, imperative that the very best efforts be expended in the preparation of general chemistry texts."[92]

The present era is characterized by the need to give fresh consideration to the introductory course. In response to this need, the General Chemistry Committee of the Advisory Council on College Chemistry convened at Tulane University, February, 1964. No attempt was made to outline a single introductory course; rather a consideration was given to a number of specific topics and specific methods of instruction which might be appropriate for freshman chemistry.

Based primarily on an outline presented by L. K. Nash of Harvard University, the following "Boundary Conditions" were offered as criteria for selecting topics in first-year chemistry:

1. The topic should be capable of natural integration into previous knowledge of the student and should add to his intellectual score.
2. The topic should be appropriate to the future activities of the student.
3. The topic and its mode of presentation should stimulate the student to take upon himself the arduous lifetime task of maximum intellectual development.
4. The first course being an introductory one, it should convey something of the nature of science.
5. The topic should be capable of honest presentation at the introductory level, with minimal extracting of rabbits from a hat or requiring the student's passive acceptance of our dogmatic assertions.
6. The topic should equip the student to solve recognizably worthwhile problems.
7. The topic should be illustrable by student laboratory experiments and lecture demonstrations.
8. The topic should be highly relevant to other subjects treated in the introductory course.

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[92] Ibid., p. 478.

9. The topic should either be a hard-core topic for introduction into the ways of chemistry, or it should not preclude the acquisition of these fundamental topics during the first-year course.[93]

The following statement was prepared with the help of all participants and represents the areas of general agreement among the participants on the topics of interest to this conference:

> The participants in this conference recognize that it is not possible to describe or develop a single first-year college chemistry program to meet the needs of all colleges and universities. Rather we believe that the strongest and most effective programs are developed by enthusiastic and dedicated teachers who take into consideration the local needs, the institutional goals and admission standards as well as national trends and creative developments in chemical education. In addition we recognize that although the quality of high school training is variable, there is a general improvement in the quality of the background of students enrolling in first-year college chemistry courses, due to the improved high school courses now available. We believe that the strongest force behind the changes now taking place in college chemistry courses is the desire to emphasize the nature of the knowledge-obtaining enterprises of the chemist and to take the student to the edge of research.[94]

The Conference recommended:

(1) Efforts be made to stimulate preparation of a series of outlines and suggestions for teaching (at the first-year college chemistry level) some important topics not adequately treated in current texts.
(2) A study be made to ascertain which additional topics traditionally treated in higher-level courses can be successfully presented in first-year college chemistry--and if such topics are treated at this level, to what extent they must be presented again.
(3) Although the entire first-year course can't be taught as rigorously as many higher-level courses, a large part of any first-year course can be presented this way.
(4) A comprehensive effort be made to continue to revitalize the laboratory work in first-year college chemistry. This can be done by uncovering and publishing new kinds of experiments and ideas.

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[93]"Editorially Speaking," p. 113.

[94]Haenisch, p. 20.

(5) Qualitative analysis be critically re-examined to see if the principles demonstrated in this work can be presented more efficiently.
(6) The use of individually prepared research-type reports patterned after a research notebook be encouraged.
(7) Where special programs for high-ability students are available, they should be provided throughout the students' college career.
(8) An optimum ratio of students to instructors be provided to give quality instruction in the laboratory. Reasonable ratios now seem to range from 10 to 16 students per instructor.
(9) Coordination between chemistry teachers and those in the other sciences be increased with a view toward reducing duplication and increasing the transfer of useful principles and information.
(10) The term "general" chemistry be discontinued and a more descriptive term be used.[95]

Nelson McKain,Jr., took opposition to the Tulane panel recommendations

The rebuttal is as follows:

> The report of the Advisory Council on College Chemistry is disturbing. The article did not state the objectives of the proposed course, not its entire content, nor the students for whom it is primarily intended. But what was said creates considerable doubt that the committee is thinking of a chemistry course for ordinary college freshmen.
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> Reading between the lines, it seems the committee does not favor a well rounded, informative, albeit rigorous, course in general chemistry, but prefers a specialized offering primarily intended to groom the freshman for graduate school. The statement that "undergraduates can begin research at the freshman level" applies to only a small percentage of any ordinary freshman class. What shall be done with the others? Will a "core" consisting of thermodynamics, the Schrodinger wave equation, and speculations on the hydrogen-oxygen bond meet the needs of students planning careers in medicine, biology, and other fields? Will such a course be suitable for the increasing number of students who take freshman chemistry as a general education course with no intention of pursuing the subject beyond the freshman year? Many good students do not enter college with a background of high school calculus, nor even a sound foundation in chemistry and physics. Can these students be given a meaningful treatment of thermodynamics in a reasonably short time? Or would it not be

[95] L. King, "Modern Texts are Needed to Update College Chemistry Courses; Freshman Often Ready for Quantum Chemistry, Thermodynamics," p. 44.

better to cover the more conventional topics thoroughly, thus laying a foundation for their future work in science? Then, as time permitted, the more advanced concepts might be introduced on a selected basis, not as a "theme" of the course. Certainly the idea of spending more than a quarter of a semester on such a specialized topic as the bonding of hydroxyl is of dubious merit in a beginning course.

It has taken our educational system more than a decade to outgrow "progressive education" and its effects still linger in places. Is the style swinging to the opposite extreme, rigor for rigor's sake? Is freshman chemistry to be made so tough that only the graduate of a two-year high school honor program can enroll? And is its content to be made useful only in meeting the requirements of a Ph.D. degree? The broadly based, informative course in general chemistry, such as is covered in many of the newer texts, meets the needs of the average college student very well, and if properly presented, will provide a challenge to the best of them. If a specialized, highly technical course is desired for a few specially selected chemistry majors, there can be no objection to its being offered. But such a course merely trains, whereas the broader course educates. The broader course provides the background of information and experiences in problem-solving needed by a variety of students in fields other than chemistry. Such a course, competently taught can be made challenging and also interesting. The students who select chemistry as a career are probably influenced more strongly by a good teacher than by course content.[96]

The previous discussions[97,98,99,100] show a diversity of approaches to the teaching of first-year college chemistry. Young's survey[101] and the AC_3 panel suggestions[102] reinforce this diversity by showing that the current available textbooks generally determine the content and outline of

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[96]McKain, p. 4.

[97]Currier, pp. 286-289.

[98]Strong and Benfey, p. 164.

[99]Williford, p. 251.

[100]Wiberly and Richtol, p. 147.

[101]Young, "The Content of the First Course in College Chemistry," p.477.

[102]"Advisory Council on Chemistry Set-Up," pp. 43-44.

the first-year chemistry course. The investigator is of the opinion that a diversity of approaches to the teaching of first-year college chemistry is pedagogically sound. The sequence in which the topics are presented and the approach that is used in the topic presentation, however, often lead to a pedagogical weakness--the lack of a conceptual framework to show how concepts are developed and related. The principle problems are coordination, distribution of topics, and arrangement of course content units in a logical and coherent sequence.

The selection guidelines for inclusion of a topic in an introductory college chemistry course were formulated by Babor,[103] Shotton,[104] Mysels[105] and Nash.[106] These discussions show that the basis for a logical arrangement of topics in freshman chemistry rather than an adherence to traditional sequence has been advocated for at least three decades. This need is also reflected by the extensive revisions and experimental innovations in the first-year chemistry course, such as the introduction of substantial amounts of physical principles, bonding theory, organic chemistry, and quantitative analytical techniques in the laboratory. AC_3 has urged that information about experimental curricula and a summary of the discussion and conclusion be made generally available. The suggestion has merit but is inadequate. The previous data and opinions give ample evidence that an analysis of the general chemistry course to identify basic unifying concepts that may allow a systemization which can provide greater effi-

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[103]Babor, pp. 263-264.

[104]Shotton, pp. 619-621.

[105]Mysels and Copeland, pp. 163-167.

[106]Nash, p. 368.

ciency and effectiveness in teaching is needed. A consolidation of the ideas of the writers mentioned in pages 23 through 38 is merited--the ensuing result being a logical, systematic procedure for the inclusion of a topic in the introductory college chemistry course, a logical arrangement of topics, a logical development of concepts to teach the processes of chemistry, and a respect for and interest in facts. The discussion by AC_3 panel members as shown on pages 35 and 36 supports the investigator's position. One solution to the controversy regarding selection of specific topics and methods of instruction would be a federal supported project that would bring together professors of chemistry from all classifications of colleges and universities with an ensuing purpose of designing introductory college chemistry courses with a concomitant analysis of the structure of the introductory course and a study of the process of teaching first-year college chemistry. Since the previous discussions have shown the textbook to be authority in regard to introductory college chemistry courses, the implication is a need for consolidation of experiences, not diversification of practices.

The General Chemistry Laboratory

There is a great deal of dissatisfaction with the present operation of freshman chemistry laboratories. Suggested solutions range from doing away with freshman laboratory to making the laboratory the center for the first-year course.[107] The present situation is comparable to the Demonstration Versus Laboratory controversy of the 1920-1940 era.[108]

[107] Haenisch, p. 17.

[108] Saul B. Arenson, "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15 (1938) p. 592.

Study of the foregoing research and opinion reflects the dissatisfaction with the teaching practices in freshman chemistry laboratory for the past 75 years and creates implications as well as questions. C. S. Adams,[109] Antioch College, in reviewing the literature of laboratory objectives of general chemistry developed a reservation regarding the tendency to consider one laboratory method superior to another. In 1942, he sent out a questionnaire to some 175 universities requesting a rating of some proposed objectives in general chemistry laboratory work. One hundred forty of these questionnaires from 140 institutions were returned. The purpose of the survey was to re-examine the general chemistry laboratory program with respect to objectives, methods, course content, methods of appraisal. Adams reported that the literature up to 1942 had recorded only two investigations, those of R. E. Horton[110] and E. O. Smith[111] which had specifically attempted to measure the outcomes, achievements and effectiveness of laboratory methods by <u>actual performance tests.</u> Adams reported that previous investigators had used paper-and pencil tests, which he believed, in probability, do not measure motor skills, manipulative ability, laboratory technique, and tangible acceptance with materials. In order to defend his position, Adams summarized the final conclusions of the two-year investigation by Horton and Smith:

1. The customary method of measuring achievement in elementary chemistry by paper-and-pencil tests measures chiefly the outcome of but one of the major objectives of laboratory work; viz., the acquisition of information.

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[109]Adams, pp. 267-268.

[110]R. E. Horton, "Does the Laboratory Belong?" Journal of Chemical Education, 5 (1928) pp. 1432-1443.

[111]E. O. Smith, "Improvement of the Individual Laboratory Exercise in Chemistry," (1929) pp. 1130-1135.

2. Such paper-and-pencil measures of achievement in chemistry fail to show any consistent or marked advantage for any of the three methods of laboratory procedure studied; viz., the individual, the lecture-demonstration, and the lecture method.
3. At the conclusion of a laboratory course in beginning chemistry those pupils who have had individual instruction do consistently better than those who have seen the experiments performed for them in class or those who have heard the instructor explain the experiments in lecture, when these pupils are measured by a laboratory performance examination.
4. This difference in ability in favor of those who have had one semester of individual laboratory instruction over those who have had the other methods of instruction is, not entirely erased at the end of the second semester.
5. Since the difference is slight it would appear that one semester of laboratory instruction by demonstration followed by a second semester of individual laboratory instruction accomplishes the same results as two semesters of individual laboratory instruction.
6. It seems probable that the best plan of laboratory procedure is to present some of the experiments, particularly during the first semester, by demonstration. The experiments involving the more complex apparatus, those in which it is most difficult to obtain the correct results, and those which may have an element of danger involved, are believed to yield the best results to the classes as a whole by the lecture-demonstration method.
7. Contrary to the conclusions of many of the previous investigators the individual method of laboratory instruction is superior, particularly for the superior student, while the lecture-demonstration method may be somewhat better for students at the lower intelligence levels.
8. Further study is necessary to obtain better methods or devices to measure the student's attainment of the generally accepted aims and objectives of laboratory work.[112]

Adams felt that more pioneering work is needed in the area of performance tests and predicted that these tests will become part of the first-year chemistry laboratory program in the not too distant future.[113] The investigator believes that the need still exists today and little evidence indicates that such tests have materialized.

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[112]Adams, pp. 267-268

[113]Ibid., p. 268.

Other educators have also shown dissatisfaction with the freshman laboratory work. Robert K. Summerbell, Northwestern University, in 1954, severely criticized the standard laboratory experiment when he said:

> We chemistry teachers sometimes defend our routine laboratory work by saying that the student is being taught by "observation." Any experienced chemistry teacher can cite numerous examples parallel to those described. No student ever learned to make observations by doing routine experiments that simply confirm statements of the text or of the instructor.[114]

Summerbell advocated the use of unknowns to improve the introductory chemistry laboratory when he had this to say:

> We have found that by introducing unknowns the value of this experiment is greatly increased. There is no longer any problem of honesty. The student is asking a question of nature, and the only way he can arrive at an answer is to make observations. He does so, and a good result gives him a real thrill. He has experienced the excitement of experiment.[115]

Summerbell concurred with Adams' plea for performance tests but, in addition, extended the evaluation problem to include not only performance but also motivation and offered the following solutions to assist professors of college chemistry:

> The evaluation of the effectiveness of teaching methods is one of the most difficult of educational problems, particularly when we are trying to measure such intangible things as student motivation. As scientists we demand measurements that can be expressed numerically. Because of the pioneering work of such a group as the Examinations Committee of the Division of Chemical Education, we know pretty well how to test efficiently such things as subject matter retention, ability to balance equations, or ability in working mathematical problems. Tests are even available for measuring competence in laboratory manipulations, or ability to apply scientific reasoning processes to a specific situation. All of these things are important and the proved validity of such tests is encouraging, but no satisfactory method of measuring motivation has come to my attention. Data can be collected as to the proportion of students electing advanced work in the field, but such data

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[114]Summerbell, p. 365

[115]Ibid., p. 366.

are subject to much random variation and hopelessly out of date by the time significant amounts have accumulated. There are, however, a number of less precise but perhaps more significant indications that are available. Do the students ask questions during, and more important, after the class? Are the students difficult to eject from the laboratory? Do they use library references and ask for more? Do they inquire about the possibility of a career in science? Do they attend unrequired public lectures in the field? Some of these criteria may be better than formalized tests as to the adequacy of the teaching. A fair portion of students who have been taught effectively should do all of these things.[116]

The general chemistry laboratory is a particularly vexing problem. Everyone agrees it should be significant and provide motivation, but the effective processes for accomplishing this have not yet been clearly defined.[117] The evidence is far from conclusive that educators really realize the educational value of laboratory. Positive confirmation of this statement is reflected in the following report on the status of the chemistry laboratory:

> What to do with laboratory in undergraduate chemistry courses remains a complex, unsolved problem despite a resurging interest now evident on a national and local scale among teachers in small and in large colleges. As this year's intake of freshmen settles into a new environment, teachers are appraising the difficulties--conceptual and physical twixt lecture and laboratory.
>
> One of the difficulties in big universities is that there are too many undergraduates, particularly freshmen, to be accommodated in existing laboratories. Relatively expensive laboratory facilities and competent staff are usually necessary to make a laboratory course challenging to students. To "solve" the problem, a few universities have abandoned freshman laboratory altogether; other schools are likely to do so. Some teachers feel, however, that teaching chemistry--an experimental science--without laboratory is analogous to training an artist without providing him paints and brushes.
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> While the problem remains unsolved, there are many chemistry teachers working on it. Several are experimenting with ideas

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[116]Ibid.

[117]Haenisch, p. 18.

to break the boundaries between the traditional subdisciplines of chemistry. One way to break these boundaries is to teach unified undergraduate laboratory courses--for example, combining physical, inorganic, and analytical; biochemistry, organic, and analytical; and organic, inorganic synthesis. Some combinations are in operation.

Although there is considerable interest in unified laboratories, there is little readily available information about what is being done and why. Nor is there much direct contact between different individuals or groups working along the same or similar lines. The Advisory Council on College Chemistry is trying to stimulate exchange of ideas among teachers and to disseminate information on the topic.[118]

The objectives of the introductory college chemistry laboratory were vividly and succinctly stated in the previous discussion by Adams on page 20. The placing of Adams' objectives in juxtaposition with the objectives of Richards, listed on page 52, show that the statement of goals for the first-year college chemistry laboratory have changed little, if any, the past forty years. The pressing need appears to be a choice of experiences to meet these stated objectives and the ensuing evaluation methods. The AC3 publications and the Journal of Chemical Education publications referred to on page 49 show the dissemination of many laboratory experiments at the introductory college chemistry level. The investigator believes the solution to the problem appears to be a consolidation and/or modification of content rather than a dissemination and exchange of ideas. The investigator believes that first-year chemistry students should receive experiences in designing open-end experiments, collecting and recording data, formulating and verifying hypotheses, drawing generalizations from data, and designing writeups. The student should be given directed-discovery experiences that allow him to discover new facts and to give him a respect for

[118]David N. Hume, "Teachers Try to Unify Laboratory Courses," Chemical and Engineering News, 45, November 20, 1967, pp. 53-54.

facts and corresponding practice in the use of data and facts. Chemistry is an experimental science, and the laboratory is an integral part and is the proper educational environment where students should learn chemistry by acting like chemists. The professors of chemistry might profit from an innovation somewhat like the Physical Science Course for Non-Science Students at Rensselaer Polytechnic Institute, New York. The suggestion of Summerbell in regard to the use of unknowns as described on page 42 might be the basis of a starting point.

Suggested Solutions to Current Controversy

Accumulated information pertaining to the first-year course content has already reached such mammoth proportions that it is impossible to include everything of importance in a first-year chemistry course. As information and new ideas proliferate, college curricula seem to become more inadequate, despite continuous efforts to upgrade courses. Since courses can't grow without limit, incorporation of new material always demands deletion of some topics which have traditionally been considered indispensable to sound chemical education. One consequence of the changes within established courses is increasing incoherence in the program as a whole. Some subjects are treated in several courses, with little attempt at cross correlation while other important topics are neglected entirely.

Admitting conjecture, in part, George Hammond[119] of the California Institute of Technology claims the time is ripe for a change and suggests a complete overhaul for college chemistry curricula. He is not expecting ready acceptance of this proposal, although the Westheimer Report,[120] in

[119]George Hammond, "Proposal Revamps Chemistry Curriculum," Chemical and Engineering News, 44, November 14, 1966, p. 48.

[120]"Westheimer Report," Chemical and Engineering News, 43, November 29, 1965, p. 48.

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essence, seems to agree with his approach. His pessimism is based upon his belief that chemists "have become highly conservative, an attitude that is inappropriate in any activity designed to produce new knowledge."[121]

Hammond's proposed freshman chemistry course, general chemistry, differs some from its current counterparts. According to Hammond, today's freshman college courses have included more and more physical chemistry with almost exclusive emphasis on structural concepts; and, although they are sophisticated and challenging, they are not "general chemistry." His proposed course in general chemistry would, hopefully, give the student a picture of the entire field of chemistry, the kinds of problems that it contains, and "various kinds of theory" used to attack problems.

The proposed general chemistry course begins,[122] much like present freshman courses and very similar to the views of Cavelti, with a discussion of elementary structural concepts--atoms, molecules, and chemical bonds, resulting in a discussion of properties of matter in condensed phases that helps introduce the student to thermodynamics. This train of thought leads to a discussion of chemical reactions, including stoichiometry problems and equilibrium. An exploration of the periodic table is guided by atomic theory and used to introduce the basic concepts of systematic inorganic chemistry. Near the end of the course, a brief discussion of synthetic chemistry makes the student aware of the field's existence, objectives and challenges.

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[121]Ibid., pp. 48-49.

[122]Hammond's proposed freshman course differs some from its current counterparts. According to Hammond, other first-year courses include more and more physical chemistry with almost exclusive emphasis on structural concepts. His proposed course in general chemistry would, he hopes, give the student a picture of the entire field of chemistry, the kinds of problems that it contains, and "various kinds of theory" used to attack problems.

Other educators are utilizing multidisciplinary (multiD) courses as the vehicle to give structure to the discipline of chemistry. Multidisciplinary courses, according to Edward C. Fuller,[123] Beloit College, Wisconsin, offered to science majors are increasing in number despite the extra demands they make on the faculty and students. Aided by the Advisory Council on College Chemistry, Fuller distributed 1600 questionnaires to determine the incidence of multiD courses offered by schools to majors and nonmajors in science. Of the 1000 returned, 75 respondents stated that multiD courses are taught to science majors. Of those 75 responses, 64 were useable and indicated that almost half of that number of institutions offered one multiD course to nonscience majors and another to science majors.

The multiD courses have been divided into elementary and advanced classes. The elementary courses usually account for six to nine semester hours in each semester of the first year. Their contents may vary considerably from college to college. For example, the Claremont California Colleges (Claremont Men's College, Pitzer, and Scripps) offered a combined chemistry-physics course in the first semester of the freshman year, followed by concurrent semesters in chemistry and physics. Florida Presbyterian College, St. Petersburg, uses a four-semester course for science and nonscience majors that includes the main topics: mechanics, chemical energetics, macromolecules, and evolution. In describing the advantages of the multiD courses, Fuller says:

> Time saving and better learning may be achieved by closely relating aspects of one discipline with a course in another. For example, teachers at Beloit College cover only the physics arising from specific aspects of chemistry in the course. Particle dynamics, work and energy, temperature,

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[123] Edward C. Fuller, "Scarce MultiD Courses Gain Ground," Chemical and Engineering News, 45, September 18, 1967, pp. 66-67.

and heat are taught to quantitate and coincide with gas kinetics and thermodynamics in chemistry. Similarly, nuclear physics and radioactivity coincide with nuclear chemistry.[124]

Some chemistry educators have responded to the plea of Robert I. Walter,[125] Haverford College, Pennsylvania, and the Advisory Council on College Chemistry[126] to offer novel suggestions in regard to introductory college chemistry laboratory. But not all agree how the student's instruction should tailor him for a place in research and industry. In answering the question, "Why have laboratory?" Charles Wilcox of Cornell University gave a comprehensive response that implied his philosophical, psychological, sociological, and pedagogical position as to the description of his concept of the present-day introductory chemistry laboratory:

> Chemistry teachers are designing new laboratory programs to counteract rapidly rising numbers of undergraduates and aging methods of laboratory instruction. Although the function of laboratory instruction should be to teach students execution and design of experiments, traditional teaching and swelling ranks of students may force the use of canned experiments whose quality is only slightly above matching blanks with predetermined answers.
>
> What's needed to reconcile student numbers with individual and meaningful instruction is a program of experimental units linked to a central theme. Such a program would be a central trunk of guided, thoroughly developed, sequential work and from this trunk several branches would provide varying degrees of detail. All students would do the work along the trunk; each would make his choice of the branch to follow.[127]

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[124]Ibid., p. 67.

[125]Walter, p. 67.

[126]Ibid.

[127]Charles Wilcox, "Teachers Devise Three Year Lab Program," <u>Chemical and Engineering News</u>, <u>45</u>, August 28, 1967, p. 74.

In its nascent form, the program's design considers fundamental approaches to preparing and purifying materials, determining compositions, and designing experiments for measuring physical and chemical properties. In terms of experiments, the program will, according to Wilcox, emphasize at all levels a sequential and conditional pattern of experimental work. The laboratory program could, in principle, accompany lecture sequences, but it dovetails most naturally the Hammond Curriculum[128] and the Advisory Council on College Chemistry modern experiments.[129,130] According to Wilcox, the first-year laboratory study will be aimed at a large number of nonmajors and smaller groups of chemistry majors.

The experiments developed by Harry Gray, Michael Smith, and Jurg Waser[131] of the California Institute of Technology advocate a different approach by including topics from diverse fields of chemistry. These three chemistry educators, in their preparation of introductory college chemistry experiments, have written experiments that show the interrelationship of inorganic and organic chemistry. One example is an experiment which involves the preparation of chromium (III) acetyl acetonate, its acetylation, and its oxidation to the triacid. The student then determines the triacid equilibrium constant and the magnetic susceptibility of the acid product. In addition, supplementary exercises have been written which would not only allow the capable student to prepare paramagnetic polymers of the triacid but would permit him to do a spectral analysis of the parent acid and its precursors.

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[128] Hammond, p. 48.

[129] Modern Experiments in Introductory College Chemistry, Stanford University, California: Advisory Council on College Chemistry, 1966, p.495.

[130] H. A. Neidig and William F. Kieffer, "Modern Experiments in Introductory College Chemistry," Journal of Chemical Education, Easton, Pennsylvania, 1967, Foreword.

[131] Wilcox, p. 74.

The first-year laboratory equipment for the experiments described above would include gas chromatographs (GC), pH meters, and other special equipment. On the other hand, alternative experiments are provided that do not require such elaborate equipment. Laboratory techniques and methods for this first-year laboratory course include: volumetric analysis, separation of solid and liquid mixtures, distillation, crystallization and sublimation, extraction, chromatography, and electrochemistry.

Ernest H. Swift of the California Institute of Technology, says that since 1956, when he moved quantitative chemistry laboratory from the sophomore year to the first two quarters of the freshman year (with qualitative analysis given in the third quarter), at least 60% more freshmen elect chemistry or chemical engineering at the end of their freshman year. Swift says:

> Quantitative techniques allow students to begin meaningful research much earlier, even as freshmen. The objectives of a quant course are not to train analysts or analytical chemists. Rather, it should develop a proficiency in planning, executing, and critically interpreting experiments involving quantitative measurement of various physical quantities.[132]

Suggested solutions to the problem of laboratory instruction differ mechanically rather than conceptually. Recently, a panel appointed by the Advisory Council on College Chemistry to study student laboratory programs concluded:

> The student has every right to expect that, on an hour-for-hour basis, the laboratory will be as stimulating as any of his activities at the university. It must compete. Does it? If not, the student is intellectually deprived.[133]

Although there is difference of opinion among AC_3 panel members regarding particular experiments to include in a program, there is a mutual

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[132] E. H. Swift, "Freshman Chemistry Laboratory at the California Institute of Technology," Journal of Chemical Education, 35 (1958) p. 44.

[133] Walter, p. 76.

agreement that laboratory is important for first-year chemistry courses. The panel was of the opinion that laboratory work in the first-year college chemistry course is moving rapidly toward quantitative experiments and that the level of such lab work demands student performance that is up to professional standards. According to AC_3, the current emphasis is on better techniques and comprehension, but fewer experiments are required. This trend, according to the panel,[134] is accompanied by the use of more instrumentation; freshmen at several schools have successfully performed experiments using instruments such as spectrophotometers and vapor chromatographs.

The panel suggested that the Advisory Council encourage a group of teachers to devise new laboratory experiments. These experiments would center on principles and ideas being introduced in first-year college courses. In addition, the panel felt that topics suitable for undergraduate research should be explored. Instead of fill-in-and-detach type laboratory texts and manuals, the use of research-type reports was urged.

The panel felt that some of the traditional lab experiments should be evaluated in light of new developments. For example, qualitative analysis, one of the oldest traditional lab exercises, should be re-examined to see if the principles demonstrated in this work can be presented more efficiently. Members of the panel believe that students should be encouraged to be more creative in applying these principles, rather than slavishly following a scheme for a given number of ions.

Recently, the AC_3 Committee on Curriculum held a conference on unified laboratories at the University of North Carolina.[135] Several teachers

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[134]King, "Modern Texts are Needed to Update College Chemistry Courses," p. 44.

[135]Hume, p. 53.

discussed programs already in operation or planned at their schools. While there are differences in details of the unified laboratory programs outlined by the conference, there is general agreement that laboratory is essential for chemistry majors and that there are some essential aspects that any successful laboratory course must have. Describing the California Institute of Technology program, John Richards[136] expresses a philosophy that he felt should be applicable to laboratory for chemistry majors--fundamentally, chemistry is an experimental science and any course must therefore contain a reasonable amount of laboratory. Richards feels that an understanding of some of the many facets of the laboratory problem requires a prior understanding of the environment in which chemistry teachers are presently working. Richards discerned the current status of chemistry laboratory when he had this to say:

> Students coming to universities now are much better prepared in theoretical topics than they were ten years ago. This is a result of improved high school science courses. But in spite of their greater theoretical sophistication, students generally have not had more laboratory experience.[137]

Richards also pointed out other perplexing problems. For example, rapid advances in theoretical chemistry and the resulting increase in complexity of experimental methods have dictated that more theory be taught. Richards feels that the response to the felt need to teach more theory has resulted in an increase in the number of units required for laboratory. To solve these problems, Richards concludes, laboratory courses must be taught in a new way, and more effectively and more efficiently. To do this, Richards says that more excitement, more enthusiasm, and more

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[136]Ibid.

[137]Ibid., p. 54.

technique must be conveyed to students than has been the case. He lists four requirements for a good experiment to achieve these goals:

1. It should demonstrate a principle.
2. It should teach a useful, modern technique; students lose enthusiasm quickly if the experiments assigned are unrelated to modern chemistry.
3. It must challenge the student. Moreover, the student himself must recognize the challenge. There are many ways to accomplish this--for instance, by artful design of the experiment, and by introducing some unknown aspect to the experiment.
4. It should be open-ended.[138]

Richards believes that if an experiment is done under an oppressive deadline the student will go through it as rapidly as possible, probably with as little thought as possible, and will probably get little out of it. If, however, a student does not feel pressed to finish a large number of experiments in a short time, his appreciation of any given experiment will be greatly increased. In defense of the open-end experiments, Richards says:

> Some material will have to be left out of the course so that as a student becomes intrigued in an open-ended experiment he can pursue it in more depth than usual. This will mean that many students will not be exposed to every technique a teacher feels necessary for successful graduate research. But the time required to learn all the techniques to an appropriate degree of proficiency is simply not available in undergraduate programs.[139]

In Richards' opinion, a few experiments done well, thoughtfully, and creatively are much more valuable to students than simply having the student go through as many "experimental recipes" as possible. Richards believes that students will be in the most advantageous position possible for further creative work as scientists if they are challenged with open-ended experiments with enough time allocated for a thorough, thoughtful

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[138]Ibid., p. 53.

[139]Ibid., p. 54.

job. Herbert O. House of Massachusetts Institute of Technology has a different view on the objective of the chemistry laboratory. In his view, the principal purpose for a chemistry major is to train him to do research. For a student not planning a research career, House feels a different type of laboratory course seems more appropriate.[140]

The rudiments of a first-rate laboratory program are inherent in the discussions of Richards and the AC_3 panel member suggestions.[141] Even though there is a difference in opinion in regard to the end product--whether student becomes a research chemist or nonscience major--the open-ended experiment appears to be the pedagogically sound basis for achieving the objectives of general college chemistry laboratory as described by Richards on page 53. The open-ended experiment, in the opinion of the investigator, would teach students execution and design of experiments and could be designed in such a manner as to show interrelationship of the different branches of chemistry as well as other disciplines of science and chemistry. The solution to the laboratory problem apparently lies in the understanding of the environment in which college professors of chemistry are working and the adaptability of open-ended experiments to fit their situations.

General Summary of Literature Review

The extensive literature review shows the introductory college chemistry curriculum to be in the midst of a revolution and has been for some

[140]Ibid.

[141]Ibid.

time. The diversity in views of different writers on what the introductory college chemistry course should be fortifies the statement[142] that no one knows just what the introductory college chemistry course is at present. The organization of the Advisory Council on College Chemistry and its vigorous activity in setting up conferences and the rapid dispensing of the writings of the panel members to the interested educators implies that an attempt is being made to consolidate and organize the introductory college chemistry curriculum in such a manner as to give structure to the discipline of chemistry. These conferences have one common weakness, however; with few exceptions, the reports carry this theme, "The remainder of this report reflects something of the diversity of opinion expressed by the participants."[143] Why not cooperation, rather than indifference?

Some educators recognize a number of forces in operation in our chemical educational environment. They recognize the flood of new information appearing in the chemical literature, especially that currently being published by the Advisory Council on College Chemistry and the American Chemical Society, and the rapid developments of complete new disciplines where there was once a borderline. They recognize the larger numbers of students beginning the study of college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and mathematics. They recognize that more equipment is available for instructional use in introductory college chemistry lecture and laboratory, and that with this equipment, some very sophisticated experiments and/or demonstrations can be moved from the upper grade levels or the graduate

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[142]Walter, p. 524.

[143]Haenisch, p. 4.

level to the freshman level. Some of the chemistry educators are responding to these forces by making an effort to bring their students in contact with the frontier of chemistry and are making an effort to create for their students a sense of participation in the processes of chemistry.

The revision of introductory college chemistry curricula, in response to the operation of some of these forces, was apparent in the discussions of George Hammond[144] and Charles Wilcox.[145] Hammond and Wilcox, through their new innovations, are adding structure to the discipline of chemistry; and they are using the chemistry laboratory to accomplish the objective it should achieve--that is, to teach students execution and design of experiments. Wilcox is coordinating the laboratory content with lecture material. The recurring theme of Wilcox's laboratory phase is "how to engineer an experiment." The curricula of Hammond and Wilcox carry one common ingredient--the student uses and develops his rational powers.[146]

Emphasis is being placed upon the coordination between chemistry teachers and those in other sciences with a view toward reducing duplication and increasing the transfer of useful principles and information. Edward C. Fuller and the Advisory Council on College Chemistry panel members[147] discussed the use of multidisciplinary courses as the vehicle to give structure to the discipline of chemistry and to give better learning by closely relating aspects of one discipline with a course in another.

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[144]Hammond, p. 48.

[145]Wilcox, p. 74.

[146]Educational Policies Commission, The Central Purpose of American Education, Washington, D.C., NEA, 1962, p. 12.

[147]Fuller, pp. 66-67.

John Richards[148] feels that in spite of the improved academic preparation high school students generally have not had adequate laboratory experience. Richards suggested open-ended experiments to overcome this limitation.

The curriculum proposals on introductory college chemistry, in general, are coming from large universities. One is impressed by the programs presented by these chemists on "how I do it"; but, on the other hand, one is puzzled as to what is happening in the other institutions of higher education. Regardless of size of the institutions, it appears that most educators agree that the development of a hard core of topics is necessary to guide what is to be taught in an introductory college chemistry course. The AC3 Committee on General Chemistry placed a tag on the controversy regarding the selection of a core of topics, even though Young had laid the framework, when they wrote:

> No attempt was made to outline a single introductory course. Rather, consideration was given to a number of specific topics and specific methods of instruction which might be appropriate for freshman chemistry and which are now in limited operation. Hopefully, these suggestions will stimulate further consideration of the methods and content of introductory chemistry.[149]

Nelson McKaine, Jr.,[150] pointed out some inherent weaknesses common to many of the new course proposals: (1) The objectives of the course were not stated and (2) the courses do not consider the students for whom they are primarily intended. Also, many of the proposed courses make no mention of evaluation or, if it is mentioned, the criteria for evaluation are so elusive and lacking that one is left pondering. Motivation is constantly discussed but remains the unsolved problem.

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[148]Hume, p. 53.

[149]Haenisch, p. 4.

[150]McKain, p. 4.

The problem then is this: Given the data which comprise the problems in chemistry and given recommendations for solutions, how can the members of the chemistry education profession resolve the personal differences in opinion regarding the application of chemical principles toward the purpose of chemistry's contribution to general education and achieve a structural pattern out of the chaos and indifference? Is such a trend evident? The evidence is far from conclusive that professional chemistry educators know what they are doing in introductory college chemistry. The findings from a survey of the teaching practices in introductory college chemistry, on the assumption that the data would indicate trends, could be of value to interested groups. Someone has said that chemistry is an experimental science; so too is its teaching.[151] Granted that this statement is valid, why don't chemists, as professional educators, get together somewhat like the secondary school innovators, consolidate their differences, and structure some introductory college chemistry courses around some stated behavioral objectives, and then devise measures to assure whether or not these goals have been achieved? The ground rules for the selection and rejection of topics have been formulated as shown by the suggestions of Babor, Deming, Mysels and Copeland, Cavelti, Nash and AC_3, and Shotton as shown on pages 23, 24, 25, 26, 35, and 24, respectively. The goals and requirements of a good laboratory experiment were well defined by Adams, Summerbell and Richards in the discussions shown on pages 20, 42, and 53, respectively. The road map has been drawn; it is not time that chemistry educators build the road.

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[151] "Editorially Speaking," p. 115.

CHAPTER III

DESIGN OF THE SURVEY

Selection of a Population

The initial statement of the problem has shown this investigation to be broad in scope. The purpose of the survey is to determine the present objectives, methods, and materials used in teaching introductory college chemistry in selected accredited colleges and universities. In order to investigate the teaching practices used in introductory college chemistry courses, sending questionnaires to those instructors in American colleges and universities who teach these courses was necessary. Institutions listed in the Office of Education directory[152] defined the population. In general, the classification scheme of institutions of higher education which was used in the questionnaire is the system in current use by the United States Office of Education.

CLASSIFICATION SCHEME: University refers to those institutions which give considerable stress to graduate instruction, which confer advanced degrees as well as bachelor's degrees in a variety of liberal arts fields, and which have at least two professional schools that are not exclusively technological. College of Liberal Arts refers to those institutions in

[152] Accredited Institutions of Higher Education. Washington: American Council on Education, September, 1967.

which the principal emphasis is placed on a program of general undergraduate education. Junior Colleges are institutions offering two-year programs of study beyond the level of the secondary school which can be credited toward a baccalaureate degree. Specialized Institutions is the category which includes schools offering degree programs directed toward one or more fields of specialization that are not attached to a liberal arts college or university. These institutions are usually adapted to such fields as technology, teacher education, and theology.

Two United States Department of Health, Education and Welfare Publications (1) Opening Fall Enrollment in Higher Education, 1966, and (2) Accredited Institutions of Higher Education (September, 1967) listed the following enrollment data for colleges and universities for the fall semester of 1966:

TABLE 1. THE 1966 FALL SEMESTER ENROLLMENT

Type of Accredited Institution	Number (N)	Enrollment Sept., 1966	Percent of Total	Mean (M)
1. Universities	236	2,753,514	47	11,667.4
2. Liberal Arts	793	1,649,232	28	2,079.7
3. Junior Colleges	400	1,081,250	18	1,703.1
4. Specialized	207	410,849	7	1,984.7
Total	1,636	5,894,845	100	3,603.2

According to Neyman,[153] the foregoing classification scheme suggested

[153] J. Neyman, "On the Two Different Aspects of the Representative Method," Journal of the Royal Statistical Society, 97 (1934) pp. 558-606.

a stratified-random sampling. Whenever a population, such as the total number of colleges and universities, is divided into such categories and some kind of random sample is taken in each category, the sample is called a stratified sample; the categories from which the sample is drawn are called strata; and the process of dividing this population into categories is called stratification. After eliminating institutions known to be closed or merged and deleting those colleges who offer graduate work only, the final list of 1,636 institutions (Table 2) was made up from those lists in the 1967 Accredited Institutions of Higher Education directory.

TABLE 2. NUMBER OF ACCREDITED INSTITUTIONS OF HIGHER EDUCATION IN THE CONTINENTAL UNITED STATES IN 1967 OFFERING INTRODUCTORY COLLEGE CHEMISTRY

State	Number of Institutions	State	Number of Institutions
Alabama	25	Nebraska	16
Arizona	8	Nevada	1
Arkansas	17	New Hampshire	8
California	172	New Jersey	29
Colorado	19	New Mexico	10
Connecticut	22	New York	139
Delaware	3	North Carolina	55
District of Columbia	15	North Dakota	8
Florida	34	Ohio	53
Georgia	45	Oklahoma	25
Idaho	8	Oregon	27
Illinois	73	Pennsylvania	93
Indiana	31	Rhode Island	10
Iowa	35	South Carolina	22
Kansas	31	South Dakota	13
Kentucky	31	Tennessee	40
Louisiana	20	Texas	83
Maine	11	Utah	9
Maryland	35	Vermont	13
Massachusetts	67	Virginia	38
Michigan	45	Washington	30
Minnesota	28	West Virginia	18
Mississippi	30	Wisconsin	30
Missouri	49	Wyoming	3
		TOTAL	1,636

Stratification

The survey was made on the basis of a sample drawn at random from 1,636 accredited institutions apparently in operation at the time. The first step used in designing the sample was to group the 1,636 institutions into four type strata of N_1, N_2, N_3, and N_4. In stratified sampling, the population of N units (1,636 institutions) is first divided into subpopulations of N_1, N_2, ..., N_L units respectively. These subpopulations are non-overlapping and together they comprise the whole of the population so that

$$N = N_1 + N_2 + N_3 + N_4$$
All institutions in the population = 1,636

To obtain the full benefit from stratification, the values of Nh (h = the population values of N_1, N_2, N_3, and N_4, respectively) must be known. When the strata had been determined, a sample was drawn from each stratum, the drawing made independently in different strata. The sample sizes within the strata were denoted by n_1, n_2, ..., n_L, respectively. The four strata were based on size, the 236 largest institutions (1966 fall enrollment) in group 1; the 400 smallest in group 4. These classifications were a compromise between the desire to report the most meaningful statistics and the practical need for holding categories to a minimum in order to facilitate and minimize the task of securing information by sampling methods.

According to Cochran,[154] stratification may bring about a gain in precision in the estimates of the whole population. The basic idea is to determine the status of introductory chemistry within each stratum as well

[154]William G. Cochran, Sampling Technique. New York: John Wiley and Sons, Inc., 1953, p. 65.

as the status for the whole population. This method of stratification was selected as the data for the subdivisions of the population (Table 1) were known and as sampling problems may differ markedly in different parts of the population. Sampling was feasible because lists of institutions (Tables 1 and 2) were available, as were enrollment statistics for practically all institutions for the 1966-67 school year.

According to Cornell,[155] (in the principle of optimum allocation) the allocation of sample size in the respective strata for a fixed total sample size requires the fewest cases to yield a given level of reliability if they are distributed among strata in proportion to the product of the number of colleges in a given population (universe) stratum. The decision to use the method of optimum allocation to determine sample size was based upon the fact that data was available (Table 1) which would allow the determination of allocations. The availability of enrollment data, according to Cornell, permits a gain in efficiency of design through stratifications. Sampling was necessary because limited resources were available and results were desired as quickly as possible.

Types of Estimates to be Used

The formulas to be used for the calculation of estimates from each classification of institution were selected from Cornell[156] and Cochran.[157] These researchers have developed the statistics for studies which utilized the method of stratified random sampling. The formula selected, adapted

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155 F. G. Cornell, "A Stratified-Random Sample of a Small Finite Population," Journal of American Statistical Association, 42 (1947) p. 523.

156 Ibid.

157 Cochran, p. 67.

from Cornell,[158] is:

$$\hat{S} = \sum_{h=1}^{L} \frac{N_h}{n_h} \sum_{i=1}^{n_h} Y_{hi} \qquad (1)$$

where $\hat{S}$ is the estimated total enrollment of all institutions in all L (L=4) strata of institutions, N is the total number of institutions in the universe or population; N_h is the total number of institutions in the hth stratum; n is the number of institutions in the sample from all strata; n_h is the number of institutions in the sample's hth stratum; and Y_{hi} is the enrollment of the ith institution in the hth stratum. The symbol $\wedge$ is used to denote an estimate of the population characteristic from the sample.

Notation

The suffix h denotes the stratum and i the enrollment within the stratum. The following symbols all refer to stratum h. (Capital letters refer to characteristics of the population and lower letters refer to those of the sample).

N_h = total number of institutions in the hth stratum of the population.
n_h = number of institutions within each hth stratum of the sample.
Y_{hi} = enrollment of the ith institution in the hth stratum.

$$\bar{Y}_h = \frac{\sum_{i=1}^{N_h} Y_{hi}}{N_h} = \text{true mean} \qquad (2)$$

$$\bar{y}_h = \frac{\sum_{i=1}^{n_h} \bar{y}_{hi}}{n_h} = \text{sample mean} \qquad (3)$$

[158] Cornell, p. 523.

$$S_h^2 = \frac{\sum_{i=1}^{N_h} (y_{hi} - \bar{Y}_h)^2}{N_h - 1} = \text{true variance} \qquad (4)$$

S_h = stratum standard deviation

For the population mean per unit, y_{st} (st for stratified), Cochran[159] suggests the formula

$$y_{st} = \frac{\sum_{h=1}^{L} N_h y_h}{N} \qquad (5)$$

as the simplest type of estimate appropriate to stratified sampling, where $N = N_1 + N_2 + \ldots + N_L$.

Determining the Size of the Sample

The problem of optimum allocation, the allocation of sample size in the respective strata for a fixed total sample size when the sampling variance is minimum, concerns the choice of the sample sizes $\underline{n_h}$ in the respective strata. In stratified random sampling, according to Cochran,[160] the variance of the estimated mean $\underline{y_{st}}$ is the smallest for a fixed total size of sample, if the sample is allocated with $\underline{n_h}$ proportional to $N_h S_h$. Cochran gives the formula below to show that the sample size in a stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or, in other words, that the sampling fraction $\underline{n_h}$ should be proportional to the $\underline{N_h}$ standard deviation (Appendix B):

$$n_h = n \frac{N_h S_h}{\sum N_h S_h} \qquad (6)$$

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[159] Cochran, p. 82.

[160] Ibid.

An expression for the minimum variance, V, is obtained by substituting the values of n_h given by formula (6) into the general formula, developed by Cornell (1947),[161] for $V(y_{st})$, where

$$V\,(y_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} N_h(N_h - n_h)\,\frac{S_h^{\,2}}{n_h} \tag{7}$$

to give

$$V \min\,(y_{st}) = \frac{1}{N^2}\,\frac{(\Sigma\, N_h S_h)^2}{n} - \frac{1}{N^2}\,\Sigma\, N_h (S_h)^2 \tag{8}$$

The method of optimum allocation requires advance estimates of the stratum standard deviation S_h. The estimate of the standard deviation was obtained from the data shown in Tables 1 and 3. The stratum standard deviation was calculated by taking the square root of the true variance equation (Equation 4) to yield

$$S_h = \sqrt{\frac{\sum_{i=1}^{N_h} (y_{hi} - \bar{Y}_h)^2}{N_h - 1}} \tag{9}$$

Cochran[162] showed that the fewest cases will be required to yield a given level of reliability if they are distributed among strata in proportion to $N_h S_h$; that is,

$$\frac{n_h}{n} = \frac{N_h S_h}{\sum_{h=1}^{L} N_h S_h}, \tag{10}$$

or

$$n_h = \frac{n\, N_h S_h}{\Sigma\, N_h S_h}, \tag{11}$$

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[161] Cornell, p. 526.

[162] Cochran, p. 65.

where $\underline{n}$ is the number of institutions in the sample from all strata, i.e.,

$$n = \sum_{h=1}^{L} nh \qquad (12)$$

The formula for determining $\underline{n}$ was derived by Cochran[163] from Equations 8, 11, and 12:

$$n = \frac{\left(\sum_{h=1}^{L} N_h S_h\right)^2}{V + \sum_{h=1}^{L} N_h S_h^{\,2}} \qquad (13)$$

or, simplifying,

$$n = \frac{(\Sigma N_h S_h)^2}{V + \Sigma N_h S_h^{\,2}} \qquad (14)$$

Since the equations for the variances of the estimated mean, Equations (1) and (2), contain both the n_h and the S_h, sample size was not determined until advance estimates of the S_h were available and some decision about allocation was made. In this survey, the standard error was not set. Instead, the coefficient of variation (C.V.) adapted from Cornell,[164] was set as follows:

$$C.V. = \frac{\sigma s}{S} = 0.05 = V \text{ (true variance)} \qquad (15)$$

This formula was used since Cornell had shown that the variance of the estimate of the enrollments, σs^2, in formula (1) was equivalent to

$$\sum_{h=1}^{L} \frac{(N_h{}^2 S_h{}^2}{n_h} \cdot \frac{N_h - n_h)}{N_h - 1} \qquad (16)$$

or the desired variance, V, equals the square of the desired standard error, σs^2.

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[163] Cochran, p. 66.

[164] Cornell, p. 526.

Since the investigator is more willing to accept false data than reject true data, the desired limit of error was set at five percent. Thus the desired standard error, according to Equation (15), is 0.05 x S, where S is the total enrollment of all desired institutions, so that the desired variance is $V = 0.0025 \times S^2$. It may be objected that enrollments will presumably be greater in 1967 than 1966 and that allowance should be made for this increase. Actually, the calculations assume only that the coefficient of variation (CV) per college remains the same in 1967--an assumption which may be questionable; but, because of the availability or unavailability of data in September, 1967, the investigator was forced to make it. Hence, Equation (14) was applied in the following form:

$$n = \frac{(\Sigma N_h S_h)^2}{0.0025\, S^2 + \Sigma N_h S_h^2} \qquad (17)$$

The allocation using equation (15) was based upon enrollments in the fall of 1966.

TABLE 3. ANALYSIS OF 1966 ENROLLMENT STATISTICS ON BASIS OF WHICH ALLOCATION OF CASES WAS MADE AMONG FOUR STRATA OF COLLEGES AND UNIVERSITIES

Stratum	h	S	S_h	$N_h S_h$	$N_h S_h^2$	n_h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Universities	236	2,753,514	10,401	2,454,634	25,530,623,688	130
Liberal Arts	793	1,649,232	2,885	2,287,805	6,599,814,781	121
Junior Colleges	400	1,081,250	3,534	1,413,600	4,996,312,677	75
Specialized	207	410,849	2,273	470,511	1,069,066,925	25
Total	1,636			6,626,466	38,195,818,071	351

Allocation Procedure Illustrated

The allocation procedure is illustrated below. The 1966 fall total

enrollment for the 1,636 institutions, S, was 5,894,845. Table 3 shows the other data which are needed to solve Equation (9).

$$n = \frac{43911151649401}{0.0025x5894845 + 38196120364} = \frac{43911151649401}{86872993935 + 38196120364} = 351.09 = 351$$

This number is distributed according to Equation (17) by means of the N_hS_h values of strata 5, column 5, of Table 3. The results of the selection of sample size in each stratum from (17) are as follows:

n_1(Universities) $= 351 \times \frac{2454633}{6626549} = 129.87 = 130$

n_2(Liberal Arts) $= 351 \times \frac{2287805}{6626549} = 121.09 = 121$

n_3(Junior Colleges) $= 351 \times \frac{1413600}{6626549} = 74.76 = 75$

n_4(Specialized) $= 351 \times \frac{470511}{6626549} = 24.92 = 25$

The results, after rounding to whole numbers, appear in column 7 of Table 3.

The statistical calculations for sample size as shown in Table 3 at the five percent limit of error, resulted in the acceptance of 130 universities, 121 liberal arts colleges, 75 junior colleges, and 25 specialized institutions; a total of 351 colleges and universities as the whole sample.

Selection of Sample

The accredited institutions of higher education, within a given stratum, were arranged in alphabetical order and were assigned numbers. The desired number of colleges within each stratum was selected by drawing a sample using a table of random numbers.[165]

[165] Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis. New York: McGraw and Hill Book Company, Inc., 1951, pp. 290-294.

In practice, the simple random sample was drawn unit by unit. The units in the population (from each state) were numbered from 1 to N_h. A series of random numbers between 1 and N_h were drawn by means of a table of random numbers.[166] The sampling described was without replacement; that is, a number that had been drawn previously was ignored since there seemed little point in having the same unit twice in the sample.

Efficiency Gained by Stratification Within the Four Type Categories

At this point it is of significance to note the efficiency which results from the stratified-random design with optimum allocation as described above. According to Cornell,[167] the usual means of determining the efficiency of a stratified sample is a comparison with an unrestricted random sample (simple random sample). If there was no stratification, that is to say, if all colleges and universities had been lumped together with the same type of estimate as in Equation (1), all institutions would, in effect, become one single stratum and the variance of the estimated total enrollment, according to Cornell,[168] would be calculated from the following equation:

$$\sigma_s^2 = \frac{N^2 S_h^2}{n} \frac{(N-n)}{(N-1)} \tag{18}$$

Substituting the proper values into Equation (18) from the data in Table 3, page 69 yields the following value for σ_s^2:

$$\sigma_s^2 = \frac{(1636)^2 (3864)^2}{351} \frac{(1285)}{(1635)} = 206{,}006{,}000{,}000$$

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[166] Ibid.

[167] Cornell, p. 529.

[168] Ibid.

The variance for all 1636 colleges and universities, as shown by Equation 14, is 86872993935. The desired stratified-random design was geared to a standard error of 294,742 or a variance of $(294,472)^2$, which is approximately 87,000,000,000.

The simple random sample variance, using Equation (18) was calculated to be approximately 206,000,000,000. According to Cornell,[169] the stratified plan used in the survey is $\frac{206,000,000,000}{87,000,000,000}$ or 2.3 times as efficient as the unrestricted random design would have been. The number of cases required on a random basis to produce the desired standard error of 294,742 would, according to Cochran,[170] be $n_o = \frac{S^2}{V}$ where n_o is a satisfactory approximation to the n of Equation (18). Substituting the data from Table 3 into the equation yields a value of $\frac{(4,876,434)^2}{206,000,000,000} = 1154$. Since the fraction $\frac{n_o}{N}$ is appreciable (that is, $(\frac{n_o}{N})$ equals $\frac{1154}{1636} = 0.71$) the following equation, adapted from Cochran,[171] was used:

$$n = \frac{n_o}{1 + \frac{n_o}{N}} \tag{19}$$

Substitution of the n_o value into Equation (19) yields:

$$n = \frac{1154}{1 + \frac{1154}{1636}} = 675.$$

The sample size of 675 would have required 41 percent of the 1636 cases.

Administration and Distribution of the Questionnaire

The questionnaire was mailed to college professors who teach the introductory college chemistry courses and a stamped, self-addressed

169 Ibid., p. 526.

170 Cochran, p. 52.

171 Ibid.

envelope was enclosed. There were two follow-ups to each questionnaire. The first was in the form of a letter with an attached postal card. The addressee was informed that a completed questionnaire had not been received from his institution, but was greatly desired. The accompanying self-addressed, return postal card contained statements to be checked by the recipient indicating disposal of the questionnaire. The card contained statements which a non-respondent could check to give reasons why he did not participate in the survey. Later, a letter signed by the investigator, was sent with a duplicate questionnaire to those who had not replied. A fair response to the appeal for completed questionnaires was had. Returns were received from colleges in all parts of the United States and from all four classifications. Only one questionnaire was returned which was not completed; two were returned about two-thirds completed and four were returned by the respondents indicating their courses do not correspond to the objectives of the survey. The tabulations of all data from completed questionnaires were made with the exception of some few individual suggestions and/or criticisms regarding procedure and materials which the investigator felt was not germane to the survey findings.

Characteristics of the Distribution

A distribution of the returns by state and classification is presented in Tables 4, 5, and 6. Those data show the number of institutions in each state to which questionnaires were sent, the number of completed returns received, and the percentage of return.

According to Garland G. Parker,[172] there are more than 2,100

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[172]Garland G. Parker, "Statistics of Attendance in American Universities and Colleges, 1966-67," School and Society, January 7, 1967.

institutions of higher education in the United States. The exclusion of graduate schools, medical schools, some theological schools, non-accredited institutions, and other institutions that do not offer first-year college chemistry from the total number of institutions resulted in the selection of 1,636 colleges and universities as the population.

TABLE 4. DISTRIBUTION OF QUESTIONNAIRES RECEIVED FROM INSTITUTIONS BY STATES

State	Number Sent	Number Returned	Percentage Return
Alabama	8	4	50
Arizona	1	0	0
Arkansas	2	2	100
California	32	17	53
Colorado	3	3	100
Connecticut	7	4	57
Delaware	1	1	100
District of Columbia	2	2	100
Florida	6	4	67
Georgia	12	11	92
Idaho	2	2	100
Illinois	23	16	70
Indiana	8	4	50
Iowa	4	2	50
Kansas	7	4	57
Kentucky	11	3	27
Louisiana	4	3	75
Maine	2	2	100
Maryland	4	3	75
Massachusetts	14	9	64
Michigan	9	8	89
Minnesota	5	5	100
Mississippi	6	4	67
Missouri	7	4	57
Montana	1	0	0
Nebraska	6	4	67
New Hampshire	2	1	50
Nevada	1	1	100
New Jersey	7	4	57
New Mexico	2	0	0
New York	27	8	30
North Carolina	8	4	50

TABLE 4. DISTRIBUTION OF QUESTIONNAIRES RECEIVED FROM INSTITUTIONS BY STATES (Continued)

State	Number Sent	Number Returned	Percentage Return
North Dakota	1	0	0
Ohio	18	6	33
Oklahoma	7	5	71
Oregon	7	4	57
Pennsylvania	19	10	53
Rhode Island	1	0	0
South Carolina	5	2	40
South Dakota	4	4	100
Tennessee	10	8	80
Texas	15	10	67
Utah	2	0	0
Vermont	1	1	100
Virginia	9	8	89
Washington	8	6	67
West Virginia	5	4	80
Wisconsin	5	5	100
Wyoming	0	0	0
TOTAL AND MEAN PERCENTAGE RETURN	351	212	60.4

The data in Table 4 indicate that the response to the questionnaire was geographically distributed. There are no returns from six states: Arizona, Montana, New Mexico, North Dakota, Rhode Island and Utah. From colleges and universities in Arkansas, Colorado, Delaware, District of Columbia, Idaho, Maine, Minnesota, Nevada, South Dakota, Vermont, and Wisconsin, 100 percent of the questionnaires were completed and returned. From institutions in Georgia, Illinois, Louisiana, Maryland, Michigan, Oklahoma, Tennessee, Virginia, and West Virginia, 70 to 92 percent were returned. Colleges from 18 states returned 50 to 67 percent of the

questionnaires. Institutions from the remaining 4 states returned from 27 to 40 percent.

Sampling by Classification of Institutions

The distribution of institutions by classification returning questionnaires is shown in Table 5. The classifications used in the questionnaire are those used by the United States Office of Education: 1. universities, 2. liberal arts colleges, 3. junior colleges, and 4. specialized institutions. Space was provided in the questionnaire for indicating classification.

TABLE 5. DISTRIBUTION OF QUESTIONNAIRES RECEIVED BY CLASSIFICATION

		Classification of Institutions			
State	Total Returns	Universities	Liberal Arts	Junior Colleges	Specialized Institutions
Alabama	4	1	3	0	0
Arizona	0	0	0	0	0
Arkansas	2	1	1	0	0
California	17	3	6	9	0
Colorado	3	2	0	1	0
Connecticut	4	3	1	0	0
Delaware	1	1	0	0	0
District of Columbia	2	1	1	0	0
Florida	4	4	0	0	0
Georgia	11	0	4	7	0
Idaho	2	2	0	0	0
Illinois	16	5	3	5	3
Indiana	4	0	3	0	1
Iowa	2	1	1	0	0
Kansas	4	2	1	1	0
Kentucky	3	3	0	0	0
Maine	2	1	0	1	0
Maryland	3	1	2	0	0
Massachusetts	9	2	5	1	1

TABLE 5. DISTRIBUTION OF QUESTIONNAIRES RECEIVED BY CLASSIFICATION (Continued)

State	Total Returns	Classification of Institutions			
		Universities	Liberal Arts	Junior Colleges	Specialized Institutions
Michigan	8	5	2	1	0
Minnesota	5	0	4	1	0
Mississippi	4	1	0	3	0
Missouri	4	2	2	0	0
Montana	0	0	0	0	0
Nebraska	4	1	3	0	0
New Hampshire	1	1	0	0	0
Nevada	1	1	0	0	0
New Jersey	4	2	0	0	2
New Mexico	0	0	0	0	0
New York	8	4	2	1	1
North Carolina	4	1	3	0	0
North Dakota	0	0	0	0	0
Ohio	6	1	5	0	0
Oklahoma	5	2	1	2	0
Oregon	4	3	0	0	1
Pennsylvania	10	4	3	1	2
Rhode Island	0	0	0	0	0
South Carolina	2	1	1	0	0
South Dakota	4	2	1	0	1
Tennessee	8	2	5	1	0
Texas	10	6	2	2	0
Utah	0	0	0	0	0
Vermont	1	0	1	0	0
Virginia	8	2	4	2	0
Washington	6	4	1	1	0
West Virginia	4	2	2	0	0
Wisconsin	5	2	3	0	0
Wyoming	0	0	0	0	0
TOTAL	212	82	77	41	12

There are 212 completed questionnaires in the survey, of which 82 were received from universities, 77 from liberal arts colleges, 41 from junior colleges, and 12 from specialized institutions. From institutions

in the four classifications, 63 percent were received from universities, 64 percent from liberal arts colleges, 55 percent from junior colleges, and 48 percent from specialized institutions.

A fair distribution (see Tables 4, 5 and 6) of colleges, both as to geographical location and classification represented, was obtained. The distribution by classification and by state is presented to show the general coverage of the survey and not for statistical justification.

TABLE 6. DISTRIBUTION OF QUESTIONNAIRES RECEIVED FROM INSTITUTIONS BY CLASSIFICATION

Classification	Number Sent	Number Returned	Number Applicable	Per Cent Returned
1. Universities	130	84*	82	63
2. Liberal Arts	121	77	77	64
3. Junior Colleges	75	41	41	55
4. Specialized	25	13**	12	48
TOTAL	351	215	212	60

*One university questionnaire was 2/3 complete and one university offered multidiversity course that did not apply.
**General Chemistry was part of General Science Course.

The Plan of Presentation of Data

The results of the survey will be presented in forthcoming tables which will describe the number and characteristics of the introductory college chemistry courses, the professional training of those professors who teach these courses, the objectives of the introductory college chemistry courses, the individual methods used by college professors to evaluate the courses and the materials and methods used in teaching

introductory college chemistry. These summations of data follow, in general, the outline as presented in the questionnaire. The topics are listed under six divisions, including twenty subdivisions; namely,

1. What are the characteristics of the introductory college chemistry courses in relation to:
   a. the number of different course titles.
   b. the number of different courses per college or university.
   c. the course prerequisites.
   d. the number of semester hours per introductory course per year.
2. What is the student's high school chemistry experience prior to enrollment in introductory college chemistry?
3. What percent of the introductory college chemistry students eventually major in chemistry?
4. What is the academic background and field specialization of college professors who are responsible for teaching introductory college chemistry?
5. What is the professional training and responsibilities of student assistants?
6. What is the typical introductory college course(s) being offered?
7. What is the teacher reaction to the utility of the current available textbooks and laboratory manuals?
8. What is teacher opinion as to what the introductory college chemistry course should be?
9. Have new introductory chemistry courses been added the past two years?
10. Has textbook change or revision and/or laboratory exercise changes or revision in the introductory chemistry course occurred in the last

two years?

11. What is the nature of the new course when compared to the old course?

12. What is the description of the introductory college chemistry laboratory with respect to:

    a. description of laboratory manual or text in use.

    b. type of pre-laboratory instruction.

    c. how students handle experimental data.

    d. what type of laboratory reports is expected of introductory college chemistry students?

13. What provisions are made to challenge academically prepared students, i.e., honors courses, independent study, conference study or sessions, advanced placement? What is the nature of the honors course? How are the students selected? What is the teacher rating in regard to best method of selection? What is the nature of independent study? Do current texts meet the needs of an honor course or independent study? What is the best description of the conference study or session? What is the nature of advanced placement? If no provisions are made for the academically talented student, what factors are given for non-participation?

14. What are the current objectives and aims of the introductory college chemistry course, especially the first five choices?

15. How are introductory college chemistry students and courses evaluated?

16. What supplementary materials, equipment, outside materials, methodology and techniques are being used to assist in the teaching of introductory college chemistry?

17. What do college professors feel to be the major limiting factors that tend to reduce student interest in introductory college chemistry?

18. What do college professors feel to be the chief factors responsible for alteration in introductory college chemistry courses?

19. What are the selected topics currently being taught in introductory college chemistry?

20. How do the findings of the survey compare with the suggestions that have been offered by the Advisory Council on College Chemistry?

Responses on the questionnaire were entered on punch cards; the data was normalized to a semester basis; a computer program was written and the data was then correlated on an IBM 1110 Computer.

The t-test was used to determine whether there is a significant difference in the practices, opinions, or methodologies of the four classifications of the population. In general, the statistical measures employed were: per cent; the mean; the standard deviation of the mean; the standard error of difference between the two uncorrelated means; and the critical ratio (t-test). Since the investigator is more willing to accept false data than reject true data, the five percent level of significance was chosen as criterion.

As a basis for discussion, when seventy-five percent of the replies are in agreement, the objective or statement is taken as generally accepted; and, when sixty-seven percent agree, there is a sufficient majority to say that the objective is accepted by most professors. A percentage of fifty-five to sixty-six indicates only possible acceptance; conversely, a response of less than thirty-three percent indicates a rejection or low usage. A variation of $\pm$ 5 percent was allowed in each instance.

CHAPTER IV

DESCRIPTION OF INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED IN INSTITUTIONS

Courses in introductory college chemistry offered in the 212 institutions surveyed are described in this chapter. The description is based on data obtained from Part I of the questionnaire. Space was provided for listing prerequisite courses, course enrollment, as well as the semester hours credit in the different introductory courses offered. Many instructors either submitted pages from the college catalog or sent catalogs describing introductory courses offered. There is a great variation in the titles as well as in the description of the courses.

The Advisory Council on College Chemistry, in 1964, suggested that a term other than "General Chemistry" be used to describe the introductory college chemistry course. Possible substitutes which were found included, "Fundamentals of Chemistry," "First-year College Chemistry," "Introductory Chemistry," or "Elementary Chemistry." Institutions are showing evidences of changing course titles, but only a few are using the suggested descriptions. The term "General Chemistry" still prevails as the most popular course name for first-year college chemistry. (Table 7, statement 15).

Titles of Introductory College Courses

The diversity of titles shown in Table 7 suggests that numerous changes are taking place in the introductory college chemistry curric-

TABLE 7. THE NUMBER OF DIFFERENT COURSE TITLES OF INTRODUCTORY CHEMISTRY COURSES

Course Titles	No. of Courses under each Title				
	Univ.	L.A.	J.C.	S.I.	Total
1. Analytical Chemistry	0	0	1	0	1
2. Atoms, Molecules, and Ions	0	1	0	0	1
3. Basic Principles of Modern Chemistry	1	0	0	0	1
4. Beginning Chemistry	0	0	2	0	2
5. Chemistry	2	1	4	1	8
6. Chemistry Laboratory Techniques	1	0	0	0	1
7. Chemical Periodicity	1	0	0	0	1
8. Chemical Principles and Introductory Analysis	0	1	0	0	1
9. Chemistry-Physics	1	0	0	0	1
10. Chemistry Survey	0	1	0	0	1
11. College Chemistry	0	0	1	0	1
12. Elements of Chemistry	0	0	1	0	1
13. Fundamentals of Chemistry	3	5	1	0	9
14. Foundations of Chemistry	1	0	0	0	1
15. General Chemistry	99	61	32	11	203
16. General Chemistry for Engineers	0	0	0	1	1
17. General Chemistry with Analysis	0	0	0	1	1
18. General Chemistry and Qualitative Analysis	1	1	1	0	3
19. General Inorganic Chemistry	0	0	3	1	4
20. General and Physical Chemistry	1	0	0	0	1
21. Inorganic Analysis	0	1	0	0	1
22. Inorganic Chemistry	7	12	2	1	22
23. Inorganic Chemistry and Qualitative Analysis	0	2	0	0	2
24. Intermediate General Chemistry	0	0	0	1	1
25. Ionic Reactions of Equilibria	1	0	0	0	1
26. Integrated Sequence of Undergraduate Chemistry	1	0	0	0	1
27. Introduction to Chemistry (Introductory Chemistry)	13	5	2	1	21
28. Introduction to Chemistry and Physics	0	1	0	0	1
29. Introductory Inorganic Chemistry	0	0	2	0	2
30. Organic Chemistry	1	0	2	0	3
31. Principles of Chemistry	10	5	0	0	15
32. Principles of Chemistry for Engineers	1	0	0	0	1
33. Quantitative Analysis	4	1	2	0	7
34. Semimicroqualitative Analysis	2	1	3	0	6
35. Solution Chemistry	0	0	1	0	1
36. Special Topics in Chemistry	1	0	0	0	1
37. Structure and Bonding	1	0	0	0	1
38. Survey of Organic Chemistry	0	0	1	0	1
39. The Role of Chemistry in the Contemporary World	1	0	0	0	1
TOTAL	154	99	61	18	332

TABLE 8. NUMBER AND PERCENT OF INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED BY INSTITUTIONS AND STUDENT ENROLLMENT

Institutions	Total No. of Courses	Number and Percent of Courses							
		One Course		Two Courses		Three Courses		Four or More Courses	
		No.	%	No.	%	No.	%	No.	%
1. Universities	154	32	39	28	34	15	18	5	5
2. Liberal Arts	99	56	72	20	25	1	1	0	0
3. Junior Colleges	61	26	63	10	24	5	12	0	0
4. Specialized	18	7	58	4	33	1	8	0	0
Total	332	121		62		22		5	
Mean Percent			57		30		10		2

Institutions	Enrollment per Year	One Course	Two Courses	Three Courses	Four or More Courses
1. Universities[a]	0-100	2	0	0	0
	101-200	8	2	2	0
	201-300	3	8	1	0
	301-400	7	3	0	0
	401-500	3	3	0	0
	501-1000	5	7	2	0
	1001-2000	3	5	6	1
	2001-3000	1	0	4	3
	> 5000	0	0	0	1
2. Liberal Arts[b]	0-100	35	7	0	0
	101-200	13	8	0	0
	201-300	2	1	1	0
	301-400	3	1	0	0
	401-500	1	0	0	0
	501-1000	2	1	0	0
	1001-2000	0	0	0	0
	2001-3000	0	0	0	0
	> 5000	0	0	0	0
3. Junior Colleges[c]	0-100	16	4	0	0
	101-200	9	1	1	0
	201-300	0	0	0	0

TABLE 8. (Continued)

Institutions	Enrollment per Year	One Course	Two Courses	Three Courses	Four or More Courses
3. Junior Colleges (Continued)	301-400	1	2	2	0
	401-500	0	0	0	0
	501-1000	0	0	1	0
	1001-2000	0	0	1	0
	2001-3000	0	0	0	0
	> 5000	0	0	0	0
4. Specialized	0-100	3	1	0	0
	101-200	2	1	0	0
	201-300	1	0	0	0
	301-400	0	1	1	0
	401-500	0	0	0	0
	501-1000	1	1	0	0
	1001-2000	0	0	0	0
	2001-3000	0	0	0	0
	> 5000	0	0	0	0
All Institutions[d]	0-100	55	10	0	0
	101-200	32	12	3	0
	201-300	6	9	2	0
	301-400	11	7	3	0
	401-500	4	3	0	0
	501-1000	8	9	4	0
	1001-2000	3	5	7	1
	2001-3000	1	0	4	3
	> 5000	0	0	0	1
Total Number of Courses[e]		120	55	23	5

[a]Two university respondents listed the number of courses but failed to list the course enrollment.

[b]Two Liberal Arts respondents listed the number of courses offered but failed to list the course enrollment.

[c]Three junior college respondents listed the number of courses but neglected to list the course enrollment.

[d]Seven institutions failed to list the student enrollment.

[e]The total number of courses does not include the 29 courses from the seven institutions which failed to list the student enrollment for their respective institutions.

culum. The 212 institutions surveyed offer a total of 332 introductory college chemistry courses excluding the course designed for non-science majors. An analysis of the data in Table 7 reflect the following subdivision in regard to course titles: 203 (61 per cent) of the courses were designated General Chemistry, 22 (six per cent) were designated Inorganic Chemistry, 21 (six per cent) were designated Introduction to Chemistry, and 15 (five per cent) were designated Principles of Chemistry; the remaining 71 (22 per cent) included a total of 35 different course titles.

Courses Offered, Course Prerequisites, and Student Preparation

The sum of the percentages listed in the "two courses," "three courses," and the "four or more courses" columns in Table 8 for each category of institutions responding reflect the following data with respect to the number of different first-year college chemistry courses offered: 57 per cent of the universities, 26 per cent of the liberal arts colleges, 36 per cent of the junior colleges, and 41 per cent of the specialized institutions offered two or more introductory college chemistry courses for science majors. The majority of the liberal arts colleges and junior colleges offer one introductory college chemistry course which is specifically designed for science majors as evidenced by the data in the "one course" column of Table 8 which shows a response offering of 56 of 77 and 26 of 41, respectively.

To determine if the number of courses offered in the institutions surveyed is a function of the number of students enrolled in the first-year college chemistry course at a given institution, the data from the

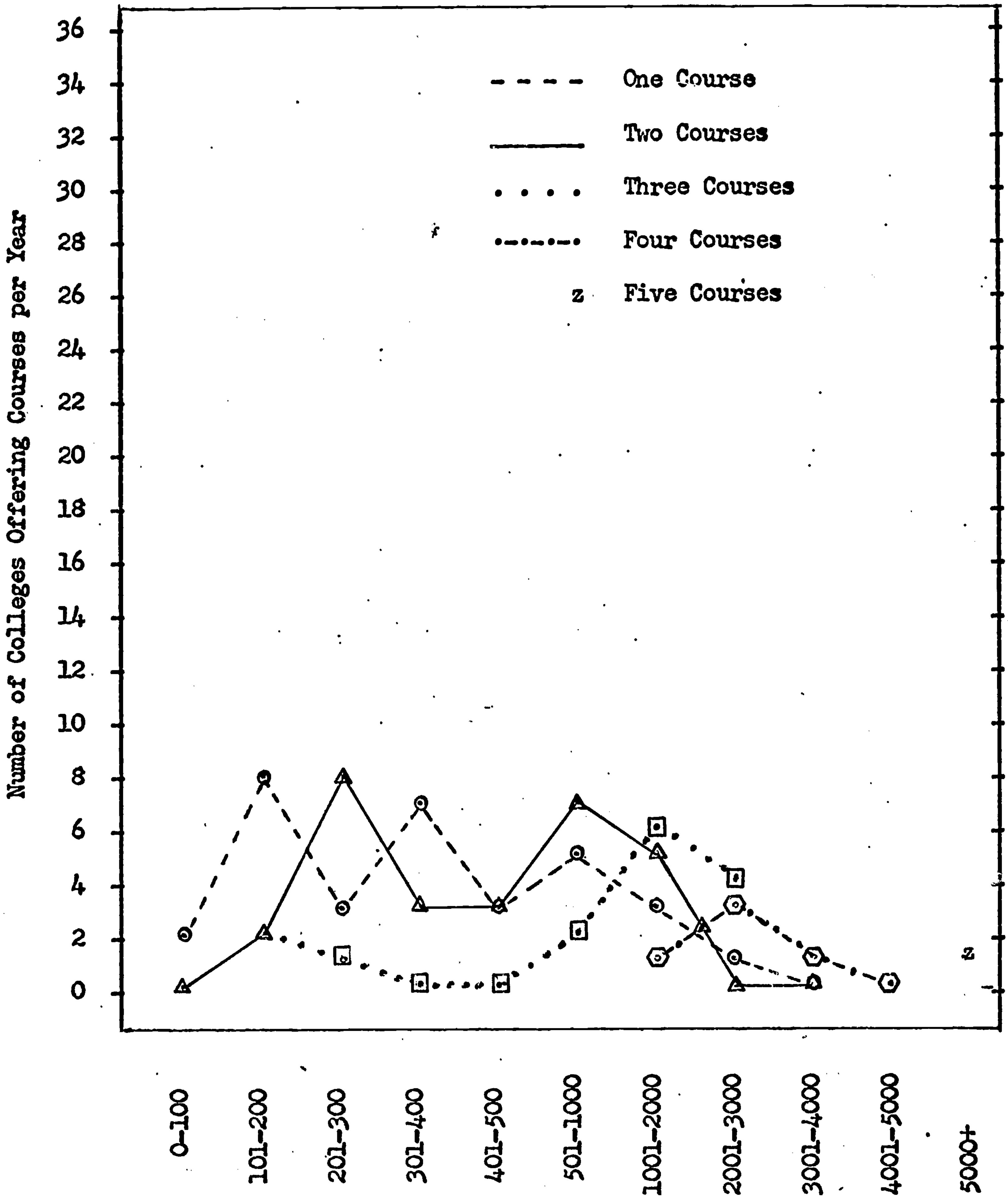

Figure 1. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Universities.*

*Two of the eighty-two respondents listed the number of courses but did not list the enrollment.

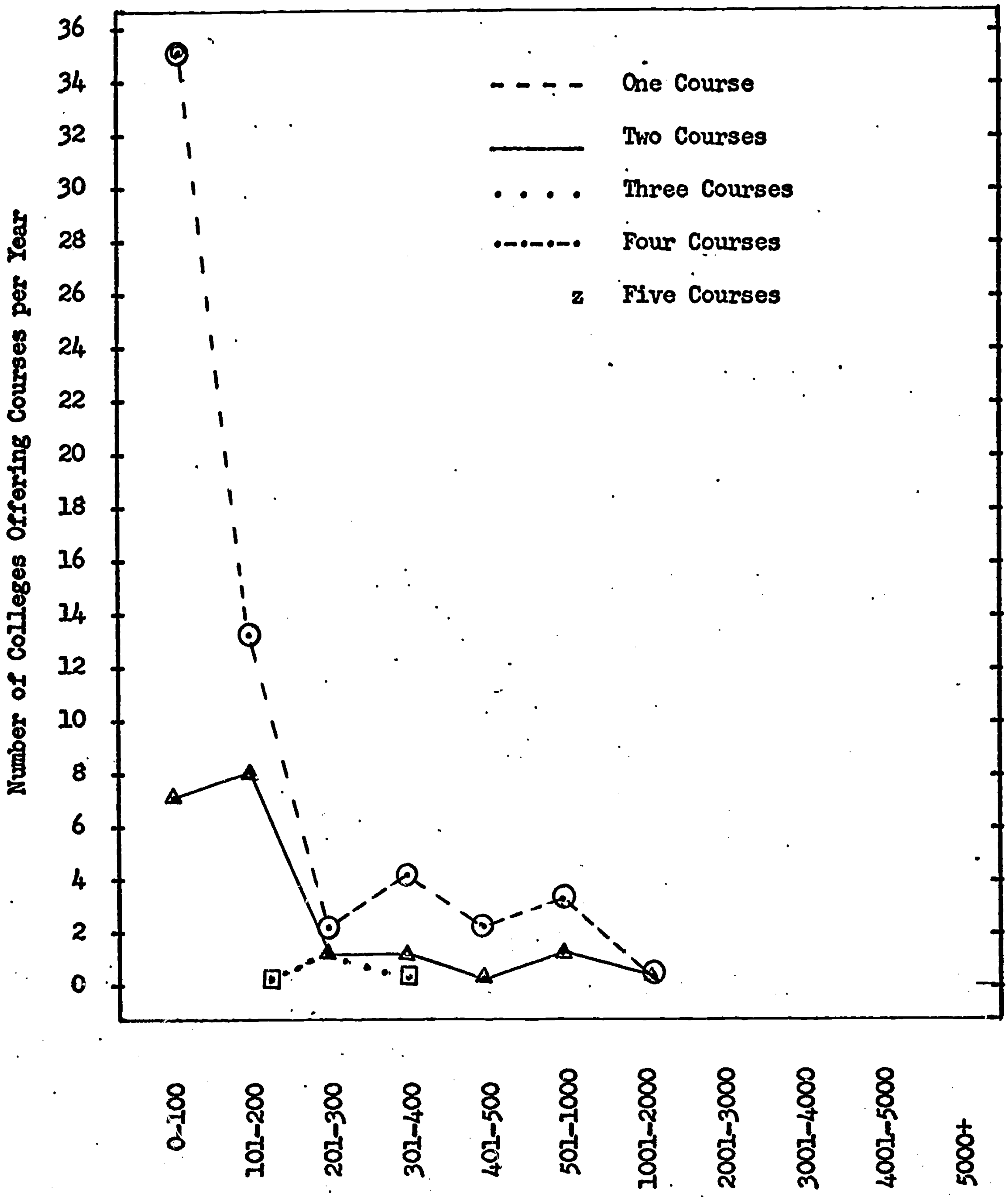

Figure 2. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Liberal Arts Colleges.*

*Two of the 77 respondents listed the number of courses but failed to list the course enrollment.

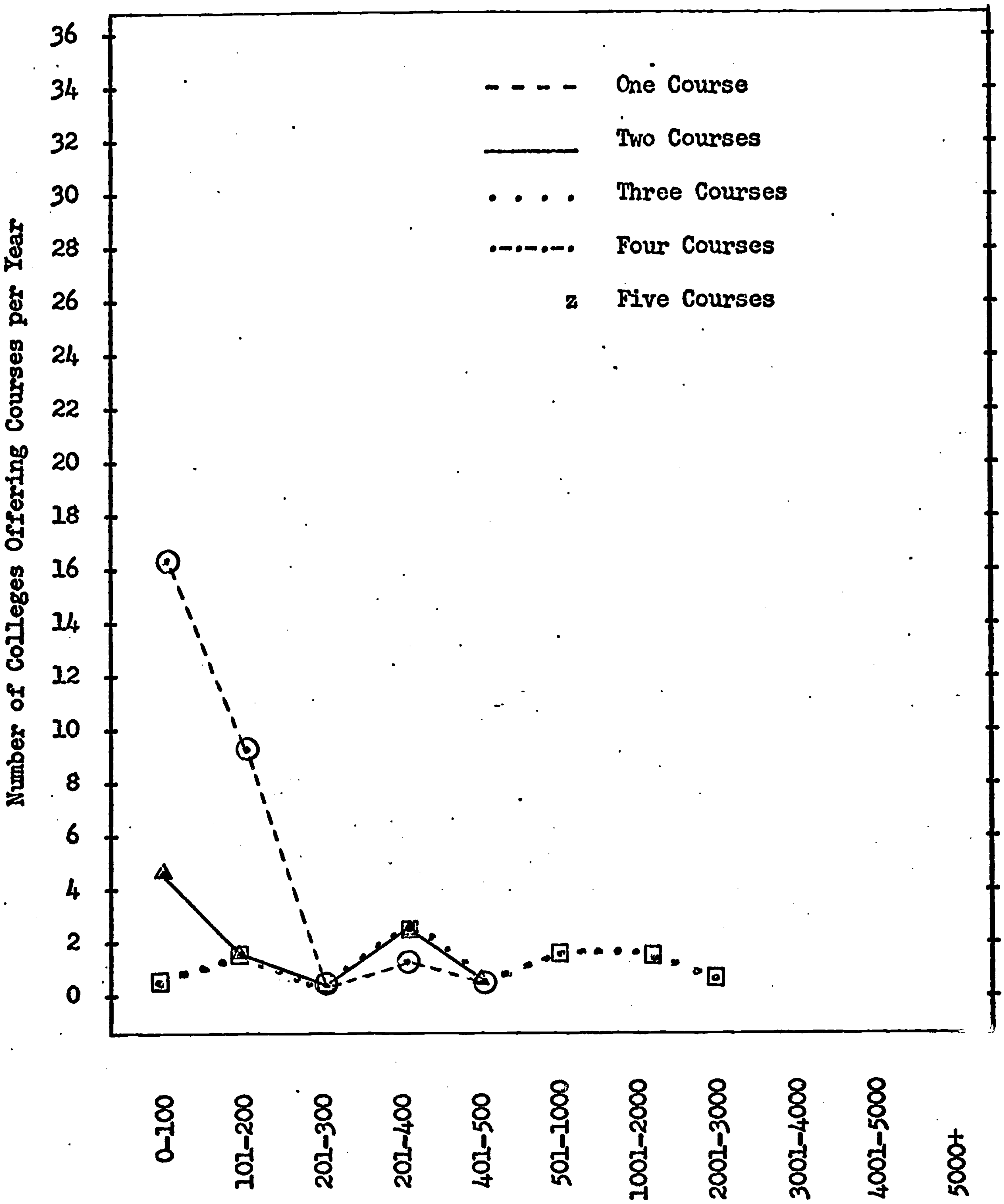

Figure 3. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Junior Colleges.*

*Three of the 41 respondents listed the number of courses but did not list the course enrollment.

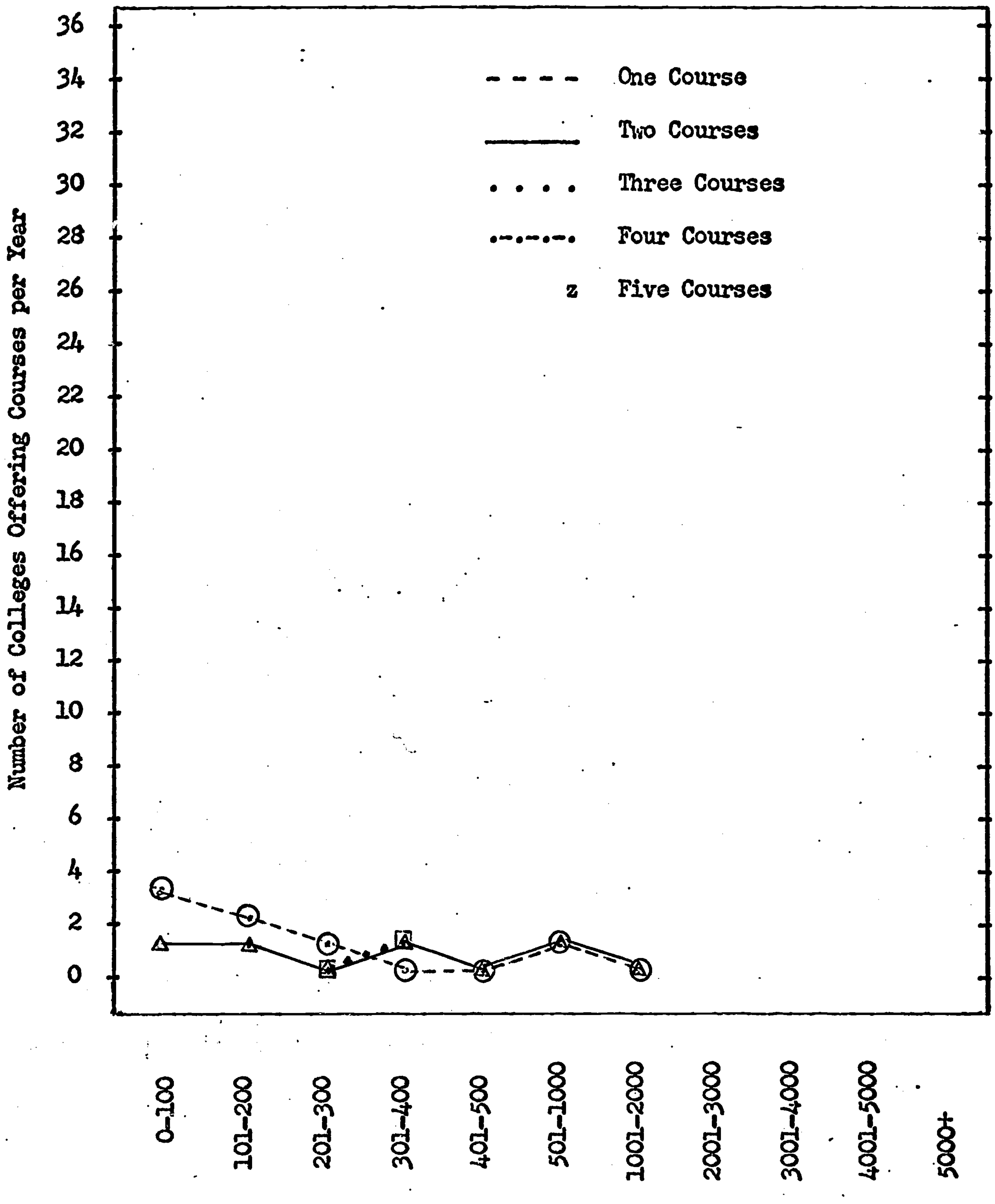

Figure 4. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Specialized Institutions.

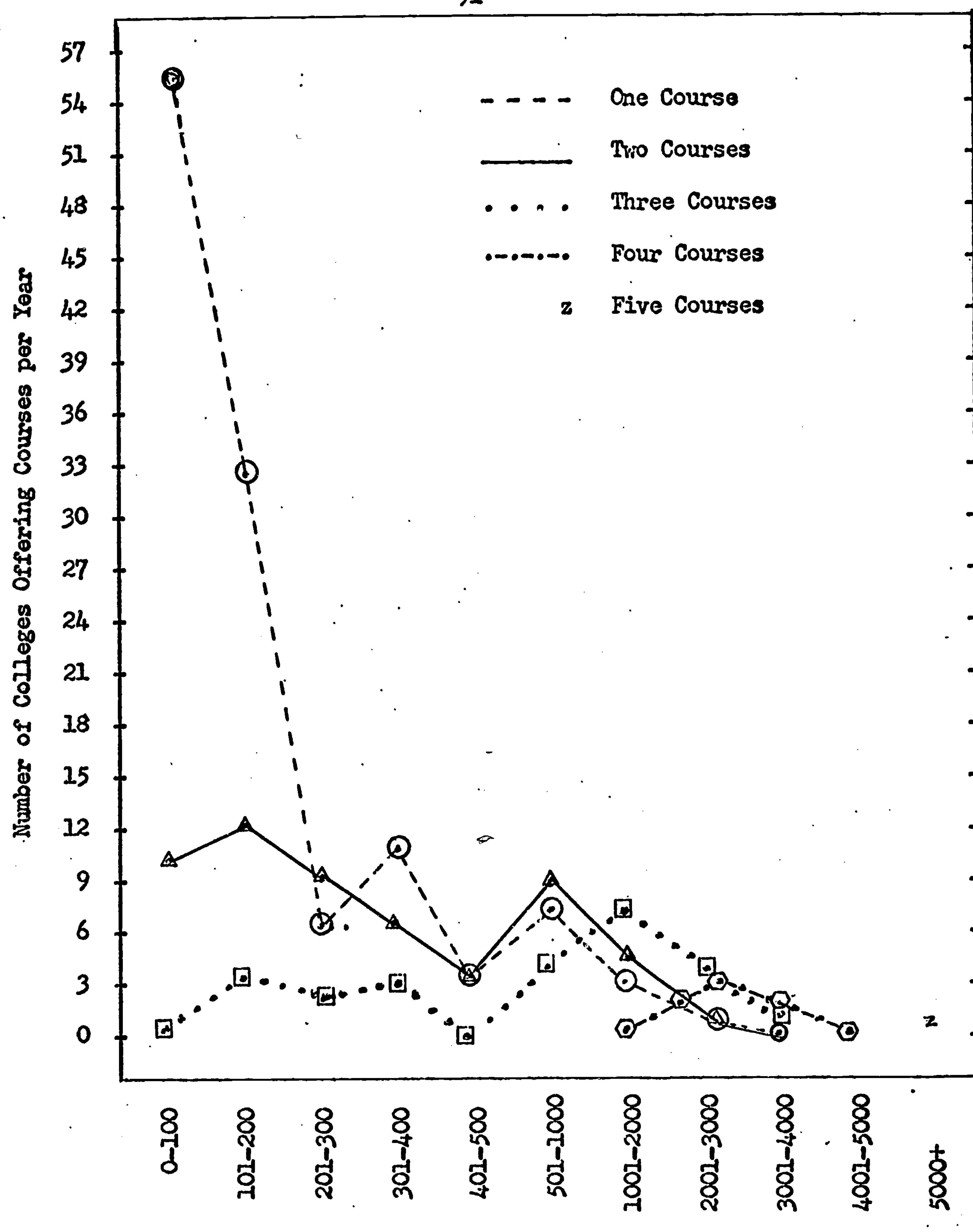

Figure 5. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in all Responding Institutions.*

*Seven of the 212 respondents did not list course enrollments.

latter portion of Table 8 was plotted in Figures 1, 2, 3, 4, and 5. In the university classification (Figure 1) the plot of the number of the universities offering courses per year versus the student enrollment in these first-year college chemistry courses show the number of different courses offered is directly related to the student enrollment when the enrollment exceeds 500. The liberal arts colleges (Figure 2), junior colleges (Figure 3) and specialized institutions (Figure 4) data plots fail to show a direct relationship between the number of courses offered and students enrollment. These three categories of institutions, as evidenced by the graphs in Figures 2, 3, and 4, indicate an almost equal offering of one and two courses per institution when the student enrollment is less than 500. In general, larger enrollments in these three categories do not show a corresponding increase in the number of courses offered as the student enrollment in first-year college chemistry increases. When a plot of the data for all institutions is made (Figure 5), the number of courses offered show a positive relationship when the student enrollment exceeds 500. Apparently the classification of college which is designing a variety of introductory college chemistry course offerings to meet the varied needs of science majors, with exceptions, is the university.

The data in Table 8 ("Total Number of Courses" column) and Table 9 ("Total" column) indicate that 204 (332 possible courses from 212 institutions listed in Table 8 minus 128 courses listed in Table 9, statement "one" which list no course prerequisites--61 per cent) of the 332 courses listed by all institutions require specific prerequisites prior to enrollment in the introductory chemistry courses; the data in Table 9 reflect

TABLE 9. PREREQUISITES TO INTRODUCTORY COLLEGE CHEMISTRY COURSES

Prerequisites	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Total
1. None	53	47	19	9	128
2. High School Preparation					
a. Mathematics (including algebra and trigonometry)	21[a]	16[a]	13[a]	3	53
b. Chemistry (one year)	41[b]	17	11[c]	1	70
c. Chemistry and Mathematics	1	1	1[e]	0	3
d. English	1	0	0	0	1
e. High School Science	1(3 yrs)	1(2 yrs)	0	0	2
f. Physics	3	0	2	1	6
g. Scholarship in High School Chemistry, Mathematics, and Physics	0	2	2	0	4
h. Upper 1/3 of class or honor	0	0	1	1	2
3. Examinations					
a. ACB (score 89% or greater)	1	0	0	0	1
b. ACE (60 or better)	0	0	1	0	1
c. ACS High School Examination	1	1	0	0	2
d. ACT	7[d]	1	0	0	8
e. Placement Test					
(1) Advanced	1	1	0	0	2
(2) Chemistry and Mathematics	1	1	0	0	2
(3) Mathematics	1	2	0	0	3
(4) Standardized	1	0	1	0	2
(5) Toledo Placement	0	1	1	0	2
f. CEEB Score (High)	1	0	0	0	1
g. Mat = 600	1	0	0	0	1
h. Predicted GPR-2 or better	1	0	0	0	1
i. SCAT	1	0	0	0	1
j. SAT (7500 or better)	1	0	0	0	1
4. College Preparation or Requirement					
a. College Algebra	1	4	2	0	7
b. Physics	0	0	1	0	1
c. Mathematics up to Calculus	2	0	0	0	2
d. Calculus Corequisite	1	1	0	0	2
e. Science Major	1	0	0	0	1
5. Other					
a. Instructor Approval	0	0	0	1	1
b. Invitation	1	0	0	0	1
c. Motivation & Achievement	1	0	0	0	1
d. Permission	1	2	0	0	3
e. Entrance Examination	4	1	1	1	7

[a]Requirements range from $1\frac{1}{2}$ years to 4 years high school math.

[b]Three require a grade of C or better; two a grade of B or better.

[c]One requires a grade of B or better; one requires 2 years high school chemistry; one requires a grade of C or better.

[d]One - 25%; one - 26%; one - 89%; one - 90%.

[e]C grade in high school chemistry and intermediate algebra.

a diversity in prerequisite requirements. Prerequisites to the courses offered were required by 101 (77 per cent) of the 154 university courses, 52 (53 per cent) of the 99 liberal arts courses, 42 (69 per cent) of the 61 junior college courses, and 9 (50 per cent) of the 18 specialized institutions courses. The most popular of these prerequisites, as shown by the various prerequisite titles listed in Table 9, are high school chemistry and/or high school mathematics including algebra and trigonometry. That 128 of the 332 courses (39 per cent) offered in all institutions surveyed required no prerequisites to introductory college chemistry course raises several questions. Do all first-year college students possess the academic preparation necessary for a successful experience in freshman chemistry or does the professor assume all students qualified and proceed to disperse the facts and principles of chemistry?

When high school experience in chemistry has been had, it is largely that of a traditional course; the data in Table 10 ("all institutions" column, the sum of items "2" and "3") show that the high school chemistry experience of students enrolled in introductory college chemistry is 68.2 per cent traditional and 14 per cent Chemical Bond Approach (CBA) or Chemical Education Materials Study (CHEM Study); a total of 82 per cent of the first-year chemistry students have had a course in high

school chemistry. These data imply that the high school chemistry experience is largely that of a traditional course; the inference being that the new secondary chemistry innovations listed above have not made an impact upon the first-year chemistry curriculum. These findings are in disagreement with the statements made by R. J. Kokes, in 1964, when he said: "...the impact of CBA, CHEM, and PSSC courses is now being felt."[173]

The data in Table 9 (prerequisite number "two," items "b" and "c") indicate that 73 of the 332 courses (22 per cent) offered in all institutions surveyed list high school chemistry and/or high school chemistry and mathematics as a prerequisite requirement to freshman, yet the data in Table 10 (sum of items "2" and "3" in "all institutions" column) infer that 82 per cent of the students who enroll in freshman chemistry in all institutions surveyed have had previous experience in high-school chemistry. How do these institutions justify their actions in either neglecting or rejecting the high school chemistry experience as a bona fide prerequisite to first-year college chemistry? Does this imply that many institutions ignore the high school chemistry training of their students and proceed on the theory that all of the subject (first-year college chemistry) must be taught to all students regardless of what was done in high school? One university professor in the survey probably reflects the opinion of many college professors by remarking:

> Students are inadequately prepared for college chemistry by virtue of weak background in English, mathematics, and physics. The vast majority of college students, were and are

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[173]R. J. Kokes, "The Present Chemistry Curriculum at the John Hopkins University," Journal of Chemical Education, 41, (1964) p. 131.

> at other like institutions throughout the nation, have not been exposed to exceptionally good high school teaching. Thus, even if he has taken chemistry in high school, he often is at a disadvantage in having to unlearn misinformation. It is my honest conviction that the high school chemistry course should either be completely abandoned completely or turned over to college professors and high school teachers of like training and ability. If this latter were done, there would be little use for a general chemistry course in the college chemistry curriculum.

Some institutions, however, are recognizing the scholastic capability and academic preparation of high school graduates. The challenge to capable students is reflected in the prerequisites listed in Table 9 (prerequisite "3") whereby a qualified student may enroll in an advanced first-year chemistry course or be promoted into an upper level chemistry course. The variety in course offerings, as shown in Table 8, also show that some institutions are designing courses to meet the student's vocational aspirations; 34 per cent of the universities offer two courses, 18 per cent offer three courses, and three per cent offer four or more courses; 25 per cent of the liberal arts colleges offer two courses and one per cent offer three courses; 24 per cent of the junior colleges offer two courses and 12 per cent offer three courses; 33 per cent of the specialized institutions offer two courses and eight per cent offer three courses. In summation, 30 per cent of all institutions surveyed offer two courses, 10 per cent offer three courses, and two per cent offer four or more courses. The data in Table 8 ("one course" column) also indicate that 57 per cent of all institutions surveyed offer only one introductory college chemistry course. Does one introductory chemistry course satisfy the needs of all science major students? The investigator is of the opinion that this question was resolved by Taylor and Hendricks[174]

[174]A description of these studies is listed in this survey, pp. 17 and 18.

two decades ago. The investigator feels that two introductory courses is the absolute minimum.

TABLE 10. PREVIOUS HIGH SCHOOL CHEMISTRY EXPERIENCE OF INTRODUCTORY COLLEGE CHEMISTRY STUDENTS AND PERCENT OF THESE STUDENTS WHO EVENTUALLY MAJOR IN CHEMISTRY

Academic Experience	Mean Per Cent of Students				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	All Inst.
1. No chemistry	9.5	11.9	22.1	4.5	12.4
2. Traditional High School Chemistry	66.7	71.5	63.1	76.3	68.2
3. CHEM Study or CBA	14.3	11.5	17.6	16.4	14.0
4. Chemistry majors	8.9	11.9	10.1	7.5	10.1

The indication in Table 10 ("all institutions" column) that 10 per cent of the students previously enrolled in freshman chemistry eventually major in chemistry is intriguing since in 1966 only 3,107 bachelor degrees in chemistry were awarded out of a total of 555,613 bachelors degrees granted.[175]

Course Credit

The diversity in course credit, as shown in Table 11, with respect to number of semester hours credit per course, semester hours per college and total number of semester hours offered is almost as great as that previously shown in course titles and prerequisites. Credit in the first experience in college chemistry ranges from two to 12 semester

[175]Gordon M. Barrow, "Dull Approach Leads to Fewer Graduates," Chemical Engineering News, 46, June 10, 1968, p. 65.

hours credit per year. The average number of courses offered per institution per year is 1.6 and the average number of semester hours credit alloted per college per year is 11.9, while the average number of semester hours assigned per course in all institutions surveyed is 7.29. The most popular schedule for the introductory college chemistry course per year as evidenced by the "8" column of Table 11 is the eight semester hour course; the second choice being the ten semester hour course (162 of the 332 courses are offered for eight hours credit and 65 are offered for ten hours credit).

TABLE 11. COURSE CREDIT IN INTRODUCTORY COLLEGE CHEMISTRY COURSES

Classification	Number of Semester Hour's Credit per Course Offered												
	2	3	$3\frac{1}{3}$	4	5	$5\frac{1}{3}$	6	$6\frac{2}{3}$	7	8	9	10	12
1. Universities	2	2	3	16	7	2	16	2	1	70	6	27	0
2. Liberal Arts	1	1	0	2	1	0	8	2	1	64	3	15	1
3. Jr. Colleges	0	4	0	5	3	3	3	3	1	18	2	19	0
4. Specialized	0	0	0	0	0	2	1	0	1	10	0	4	0
TOTAL	3	7	3	18	11	7	28	7	4	162	11	65	1

	Credit in Semester Hours per Course and per College			
	Total No. of Courses	Total No. of Semester Hrs.	Semester Hrs. per Course	Semester Hours per College
1. Universities	154	1130	7.40	13.8
2. Liberal Arts	99	787.3	7.85	10.2
3. Jr. Colleges	61	460	7.54	11.2
4. Specialized	18	143.7	8.00	12.0
TOTAL	332	2521.0		
MEAN	1.6	11.9	7.29	11.9

Academic Fields and Degrees of Chemistry Professors

The questionnaire requested the name of the professor in charge of the introductory college chemistry course, the highest degree held and the field in which it was earned. The request was also made that the number of other professors teaching introductory chemistry, lecture or laboratory sections, be indicated with the field of specialized and degree held by each.

The number of professors teaching introductory college chemistry courses, as shown in Table 12, refers to full-time and part-time professors. All professors so listed are understood to be teaching one or more lecture or laboratory sections in introductory college chemistry or to have duties in connection with the courses.

From Table 12, one will note that there are 459 professors teaching introductory college chemistry in 82 universities; 224 in 77 liberal arts colleges; 105 in 41 junior colleges; and 48 in 12 specialized institutions--a total of 836 professors in 212 institutions. This is an average of more than five professors per university, less than three for each liberal arts college, less than three for each junior college, and four for each specialized institution or a mean average of approximately four for the 212 participating institutions. Computing a statistical average of the personnel involved in first-year chemistry is not possible because some institutions indicated a variety in number of instructors each year due to fluctuations in student enrollment. Approximately 89 per cent of the university professors have earned doctoral degrees in chemistry and eight per cent have completed master degrees in chemistry. Similar information is shown for the other institutions (See Table 12).

TABLE 12. ACADEMIC FIELD AND HIGHEST DEGREE EARNED BY PROFESSORS OF INTRODUCTORY COLLEGE CHEMISTRY

Field of Specialization and College Degree	Number of Professors				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Number of Professors
Chemistry					
Bachelors	6	6	0	0	12
Masters	38	37	69	20	164
Doctorate	409	170	19	25	623
Chemistry Education					
Masters	0	0	2	2	4
Chemical Engineering					
Bachelors	1	0	0	0	1
Doctorate	0	1	1	0	2
Pharmaceutical Chemistry					
Doctorate	0	1	0	0	1
Science Education					
Masters	1	1	2	0	4
Doctorate	0	0	0	1	1
Education					
Bachelors	0	0	1	0	1
Masters	2	1	5	0	8
Doctorate	2	1	1	0	4
Biology					
Bachelors	0	0	1	0	1
Masters	0	2	1	0	3
Botany					
Masters	0	0	1	0	1
Zoology					
Masters	0	0	1	0	1
Clinical Pathology					
Masters	0	1	0	0	1
Pathology					
Doctorate	0	1	0	0	1
Horticulture					
Bachelors	0	0	1	0	1
Physics Education					
Masters	0	1	0	0	1
Pre-Medical					
Bachelors	0	1	0	0	1
TOTAL	459	224	105	48	836
AVERAGE NUMBER OF PROFESSORS PER COLLEGE	5.5	2.9	2.6	4.0	3.9

TABLE 13. FIELD AND DEGREE OF PROFESSORS IN CHARGE OF INTRODUCTORY CHEMISTRY COURSE

Field and Degree	Univ.		Lib. Arts		Junior Colleges		Spec. Inst.		All Respondents	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chemistry										
Bachelors	1	1	0	0	0	0	0	0	1	.5
Masters	4	5	14	18	29	71	3	25	50	24.0
Doctorate	77	94	59	77	1	2	6	50	143	67.0
Chemistry Education										
Masters	0	0	2	3	1	2	2	17	5	2.0
Education										
Bachelors	0	0	0	0	1	2	0	0	1	.5
Masters	0	0	0	0	4	10	0	0	4	2.0
Zoology										
Masters	0	0	0	0	1	2	0	0	1	.5
Horticulture										
Masters	0	0	0	0	1	2	0	0	1	.5
Science Education										
Masters	0	0	0	0	1	2	0	0	1	.5
Doctorate	0	0	0	0	0	0	1	8	1	.5
Pathology										
Doctorate	0	0	1	1	0	0	0	0	1	.5
Chemical Engineering										
Doctorate	0	0	0	0	1	2	0	0	1	.5
Botany										
Masters	0	0	0	0	1	2	0	0	1	.5
Biology										
Masters	0	0	1	1	0	0	0	0	1	.5

The data in Table 12, ("number of professors" column) reflect that the highest degree held by 12 (1.4 per cent) of the first-year chemistry professors from all participating institutions is a bachelors degree in chemistry and that 37 professors (4.4 per cent) have received their professional education in a field of specialization which requires a background in chemistry but is not the discipline chemistry *per se*. According to the data in Table 12 ("university" column), academic training of

the first-year college chemistry professors is in 14 different fields of specialization, including chemistry, with 623 professors ("number of professors" column) out of a total of 836 (75 per cent) having earned a doctoral degree in the discipline of chemistry. A summary of the data in Table 12 ("number of professors" column) reflect the following distribution in regard to the various number of the different highest degrees held by the professors from all types of institutions teaching the introductory course in college chemistry: 17 bachelors degrees—12 in chemistry; 187 masters degrees—164 in chemistry and 632 doctoral degrees—623 in chemistry.

The data in Table 13, ("all respondents" column) infer that of the professors in charge of the first-year college chemistry courses, 67 per cent have earned the doctorate in chemistry, 0.5 per cent in science education, 0.5 per cent in pathology, and 0.5 per cent in chemical engineering (these latter three are related science fields); a total of 68.5 per cent. Of the 212 supervising college chemistry professors, 24 per cent have completed, as their highest academic degree, the masters degree in chemistry, two per cent in chemistry education, 0.5 per cent in science education (a total of 26.5 per cent) while less than nine per cent are educated in a science other than chemistry including education. The data in Tables 12 and 13 also show, like other surveys, a need for more professors with earned doctorates in chemistry or chemistry education, especially in junior colleges. The number of graduate assistants who teach or assist in the teaching of the lecture phase of the first-year college chemistry course was not compiled in these statistics.

College professors need teaching assistants, and the lack of professional trained personnel has resulted in the utilization of student

TABLE 14. PROFESSIONAL TRAINING AND RESPONSIBILITIES OF STUDENT ASSISTANTS

	Number of Student Assistants				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Total
Degree					
None	115	281	93	15	504
Bachelors	733	29	2	31	795
Masters	148	10	0	10	168
Doctorate	4	0	0	0	4
Other[a]	137	0	0	0	137
Responsibility					
1. Lecture	13	0	1	1	15
2. Lab setup or lab supervisor	1052	259	21	[illegible]	1338
3. Chem. preparation for lecture and/or lab	12	72	5	1	90
4. Stockroom	28	20	5	0	53
5. Grade papers, exams, report sheets or proctor exams	148	54	2	1	205
6. Cleanup	0	0	3	1	4
7. Recitation	322	9	0	2	333
8. Prepare and/or repair equipment	0	0	2	0	2
9. Tutor (help sessions, discussions, etc.)	74	0	1	0	75
10. Prelab or lecture demonstration	0	0	2	0	2
11. Conferences	27	0	0	0	27
12. Reading	0	1	0	0	1
13. Clerical (inventory, budget supply, order equipment)	0	0	1	0	1
14. Answer questions	0	0	1	0	1
15. Correct homework	0	12	0	0	12
Number of Assistants	1137	320	95	56	1608
Colleges indicating no assistants	6	10	9	5	40
Colleges with assistants	76	67	32	7	182
Range	0-70	0-30	0-6	0-29	0-70
Average per College	14.9	4.7	3.0	4.7	7.5

[a]Degree indicated but level not specified.

assistants (Table 14). The responsibilities allocated to student assistants (Table 14) are numerous. Of the 212 institutions surveyed, 182 (86 per cent) utilize the services of student assistants. The most popular use of student assistants is either in preparing for laboratory or as laboratory supervisors. Priorities two and three for student assistants include paper grading and conducting recitation sections respectively.

The data in Table 14 indicate the quantity and not the quality of the assistants. Since 504 out of 1,608 student assistants (31 per cent) have no college degrees and 795 (49 per cent) have only completed the bachelors degree, questions could probably be raised about the quality of the assistants. Those instructing both lecture and laboratory should be well trained, however, the limited supply of well trained teachers now and in the forseeable future indicates the need to utilize student assistants of lower training for routine tasks such as paper grading and routine laboratory work.

CHAPTER V

THE INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED AT THE ACCREDITED INSTITUTIONS

Typical Introductory Chemistry Courses

The Advisory Council on College Chemistry (AC_3) has described the first-year college chemistry course as ranging in content from largely descriptive to largely theoretical.[176] The literature does not show an investigation which has attempted to describe the typical course nor the number of different introductory college chemistry courses that are currently being offered per institution. Taylor and Hendricks[177] gave sufficient evidence to indicate that at least two different first-year college chemistry courses should be offered--one course for science majors and a different course for nonscience majors. The survey data in Table 15, however, infer practices contrary to the suggestions of Taylor and Hendricks by showing that only 42 per cent of the universities, 25 per cent of the liberal arts colleges, 10 per cent of the junior colleges, and 50 per cent of the specialized institutions (30 per cent response from all institutions) surveyed offer several courses of varying difficulty. The data in Table 15 ("Total" column) show that 59 per cent of the institutions pay no attention to the chemistry background of the student, and the ensuing practice is to place all students in the same

[176] Haenisch, "The Content of Introductory College Chemistry," p. 21.

[177] Taylor and Hendricks, pp. 17-18 of this survey.

TABLE 15. TYPICAL INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED

Type of Course	Univ.		Lib. Arts		Jr. Coll.		Spec. Inst.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. No distinction as to chemistry background. All students take same course.	42	51	49	63	28	68	7	58	126	59
2. Course is designed in such a way that the better prepared student can complete the equivalent of one year course in one semester.	11	13	7	9	3	7	2	16	23	10
3. Place all students together but compensate for the student who has had no prior study in chemistry by using some of the early laboratory periods as drill sessions to give students experience in nomenclature, elementary facts of atomic theory, and equation writing.	5	5	12	15	6	14	1	8	24	11
4. Selected students are given a brief review and then placed in an honors section by examination.	7	8	7	9	0	0	0	0	14	6
5. Offer several introductory chemistry courses of varying difficulty.	37	42	18	25	6	10	6	50	66	30
6. Give a sufficiently different course in the laboratory such that no student feels he is repeating the course. Try to eliminate trivia and introduce advanced and nontraditional topics.	22	26	34	44	7	17	1	8	64	30
7. Other										
(a) Courses designed so that each student may attain to the utmost of his ability.	16	20	6	8	0	0	0	0	22	10
(b) Teach no lab first semester; 6 hours per week in second semester using analytical balances, etc.	1	1	0	0	0	0	0	0	1	0
(c) Organic.	1	1	0	0	0	0	0	0	1	0
(d) Special curricula (nurses, environmental health, and home economics) take special courses during third quarter of general course--others continue study of general chemistry.	1	1	0	0	0	0	0	0	1	0
(e) A course in chemical principles with a minimum of descriptive math.	1	1	0	0	0	0	0	0	1	0

TABLE 15. (Continued)

Type of Course	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. Inst. No.	Spec. Inst. %	All Inst. No.	All Inst. %
7. Other (continued)										
(f) Offer special problems course for weaker students.	0	0	0	0	1	2	0	0	1	0
(g) Some students take the non-science major course and then enter the science major course.	0	0	0	0	1	2	0	0	1	0
(h) Programmed materials are used with weaker students.	0	0	0	0	1	2	0	0	1	0
(i) Course designed to challenge students.	0	0	0	0	6	14	0	0	6	3
(j) One course for science majors and another for non-science majors.	0	0	1	1	0	0	1	8	2	1
(k) Students are placed in a difficult course by examination.	0	0	1	1	0	0	0	0	1	0

first-year college course. Close examination of the data in Table 15 infers that the picture is not hopeless, since 30 per cent ("All Institution" column, item "5") of the responding institutions indicated that they offer several introductory chemistry courses of varying difficulty; and, in addition, an equivalent percentage (item "6") offer a course which is sufficiently different in the laboratory phase so that no student feels he is repeating the same course. The data ("Total" column, Type of Course "7-a") also show that 10 per cent of all institutions surveyed are designing courses in which the student may achieve to the utmost of his capabilities.

TABLE 15-A. T-TEST OF SIGNIFICANCE

Topic	Groups of Institutions Compared					
	J.C. vs. Spec.	L.A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J.C.	Univ. vs. L.A.	L.A. vs. J.C.
Degrees of Freedom	51	87	92	121	157	116
T-score at .05 Probability	2.01	1.99	1.99	1.98	1.98	1.98
Course Description (See Table 15)	t-test (1)	(2)	(3)	(4)	(5)	(6)
1	0.618	0.346	0.451	1.797	1.574	0.498
2	0.942	0.792	0.298	0.992	0.851	0.324
3	1.301	1.419	0.107	3.067*	3.542*	0.171
4	0.000	1.076	1.041	1.928	0.122	1.995*
5	1.134	1.324	0.362	2.179*	2.910*	0.132
6	0.721	2.393*	1.380	1.190	2.295*	3.006*

*Significant at the five per cent level of confidence

The t-test scores in Table 15-A yield little information regarding a comparison of the means of the statement responses with respect to teacher reactions to statements describing the introductory college chemistry courses (Table 15) offered by the different institutions and any generalizations would be misleading since the per cent response is too low to distinguish a statistical difference. A comparison of the tabulations in Tables 15 and 16, however, yield data which reveal that teacher practices in introductory college chemistry (Table 15) and teacher reactions to statements describing the introductory chemistry course (Table 16) to be incongruous. The data in Table 15 (statement "1") show that 58 per cent of the institutions surveyed ignore the high-school chemistry background of students and the ensuing practice is to place all students in the same course, while the data in Table 16 (statement "1") show that only 33 per cent of the respondents from all institutions surveyed agree that the present first-year chemistry course is generally satisfactory for all students. The data in Table 16 (statement "2") show that 41 per cent of all respondents agree that the present course being taught at their institutions is most appropriate for the chemistry major, also 41 per cent disagree, while 12 per cent remain undecided. Such an indecision was not evident in the junior colleges since the junior college professors by a 56 per cent affirmative response ("Total" column, statement "2") agree that the current first-year college chemistry course is more appropriate for chemistry majors.

The data in Table 16 (Statement "3" of "Total" column) show that 58 per cent of the respondents (a possible acceptance) favor the practice of significantly modifying the first-year college chemistry course specifically designed for the superior students with a good academic background

TABLE 16. PERCENT OF TEACHER REACTIONS TO STATEMENTS CONCERNING THE CONVENTIONAL COURSE IN COLLEGE CHEMISTRY

The "conventional" course in college chemistry:	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	D[b]	U[c]	A	D	U	A	D	U	A	D	U	A	D	U
1. is generally satisfactory for all students.	26	58	9	40	40	15	29	48	19	50	41	8	33	49	13
2. is more appropriate for students who major in chemistry than those who do not.	37	48	10	38	27	18	56	34	4	33	50	16	41	41	12
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	53	36	6	57	29	7	69	19	9	66	16	16	58	29	8
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry.	18	52	21	14	46	29	21	41	29	25	41	33	17	47	26
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	41	18	30	53	11	27	58	9	26	41	25	25	49	14	28
6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to CBA and CHEM study at the introductory college level.	34	34	23	28	35	23	31	34	21	8	50	41	30	35	24

[a] A - Agree [b] D - Disagree [c] U - Uncertain

in high school mathematics and science by eliminating some descriptive matter and introducing advanced non-traditional topics. An observation is also made which invigorates one's curiosity: the professors, by a 93 per cent approval (See Table 27, p. 155), accepted the general objective of introductory college chemistry as "the development of the ability to do critical thinking," however, only 49 per cent of the total number of professors responding agree that the course should be taught from textbooks of varying difficulty and utilizing the inquiry approach while another 28 per cent remained uncertain in their decision (Table 16, item "5" of the "All Institutions" column). A closer examination of the data (Table 16, item "5") however, shows that 58 per cent of the junior colleges and 53 per cent of the liberal arts colleges (an indication of a possible acceptance) agree on the use of textbooks of varying difficulty utilizing the inquiry while the response from all institutions surveyed (Table 16, statement "5") is only a 49 per cent agreement to the use of textbooks of varying difficulty and utilizing the inquiry approach.

TABLE 16-A T-TEST OF SIGNIFICANCE

Topic	Groups of Institutions Compared					
	J.C. vs. Spec.	L.A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J.C.	Univ. vs. L.A.	L.A. vs. J.C.
Degrees of Freedom	51	87	92	121	157	116
Statement (See Table 16)	t-test scores (1)	(2)	(3)	(4)	(5)	(6)
1	1.091	0.380	0.679	0.875	0.474	1.177
2	1.952	0.566	0.685	2.202*	0.044	1.965
3	0.555	0.429	0.227	0.652	0.441	0.266
4	0.531	0.392	0.748	0.221	0.605	0.268
5	0.254	0.268	0.090	0.573	0.695	0.005
6	2.233*	2.187*	2.207*	0.338	0.206	0.157

*Significant at the five percent level of confidence.

The t-test is used to determine if there is a significant difference, at the five per cent level of confidence, between the means of the teacher reactions in the various categories with respect to rating of a preselected list of statements concerning the conventional (the current) introductory college chemistry course. A t-test score of 1.98 in column four of Table 16-A would show a significant difference at the five per cent level of confidence. The critical ratio between the junior college and the university professors responses to the statement, "the conventional course in college chemistry is more appropriate for the students who major in chemistry than those who do not," is 2.202. This critical ratio (t-test) shows that junior college professors reactions to the statement above, when compared with the opinions of university professors, believe the present introductory course in college chemistry is more appropriate for the chemistry major than the non-major than do university professors.

A t-test score of 2.01 in Table 16-A, column "1", and a t-test score of 1.99 in Table 16-A, columns "2" and "3", would show significant difference at the five per cent level of confidence. The critical ratios with respect to the statement, "the conventional course in college chemistry will continue because time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to Chemical Bond Approach (CBA) and Chemical Education Materials Study (CHEMS Study) at the introductory college level," as shown in Table 16-A, columns "one," "two," and "three," are 2.233, 2.187 and 2.207 in favor of the junior college, liberal arts college and university when the means of these institution's responses are compared with the specialized institutions. These t-test scores show that a significantly smaller number

TABLE 17. TEACHER OPINIONS ON WHAT THE INTRODUCTORY COURSE IN COLLEGE CHEMISTRY SHOULD BE

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. A course in chemical principles with descriptive chemistry serving only to illustrate these concepts.	56	68	50	64	28	68	9	75	143	67
2. A course based heavily on laboratory and classroom demonstration of a phenomenon.	4	4	2	2	5	12	0	0	11	5
3. An integrated course in physics, chemistry, and mathematics.	4	4	8	10	5	12	1	8	18	8
4. An inventory of factual materials and phenomenological formulas needed for advanced study.	1	1	2	2	1	2	0	0	4	1
5. Other										
(a) Choice (1) with a course in chemical principles with a sizeable amount of descriptive chemistry--more than just enough to illustrate principles--enough to show the principles are valid and to give the student an appreciation for the wide applications of chemistry in many areas.	1	1	0	0	0	0	0	0	1	0
(b) Choice (1) with a balance between principles and descriptive materials. Students must learn chemical reactions sometime.	2	2	0	0	0	0	1	8	3	1
(c) Chemical principles and descriptive chemistry along with adequate laboratory.	2	2	0	0	0	0	0	0	2	0
(d) Combination of (1) and (2) above, equivalent amounts of each.	1	1	1	1	1	2	0	0	3	1
(e) Basic principles, historical background for perspective emphasis on scientific method, relevance to common experience.	1	1	0	0	0	0	0	0	1	0
(f) A course in chemical principles heavily endowed with phenomena observed in the laboratory and text to illustrate these principles. Integration with math is necessary to illustrate and utilize transfer of ideas. Descriptive chemistry MUST be brought back to show how principles are derived.	1	1	0	0	0	0	0	0	1	0

TABLE 17. (Continued)

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
5. Other (continued)										
(g) Choice (1) with enough descriptive chemistry to count.	1	1	2	2	0	0	0	0	3	1
(h) Almost Choice (1) but add separate sections on descriptive chemistry.	1	1	0	0	0	0	0	0	1	0
(i) 3/5 of Choice (1) and 2/5 of Choice (2).	1	1	0	0	0	0	0	0	1	0
(j) Choice (1) but include organic and biochemistry in descriptive.	1	1	0	0	0	0	0	0	1	0
(k) Choice (1) but add problem solving emphasis.	1	1	0	0	1	2	0	0	2	0
(l) Our course is an "introduction to a scientific lab" in which students learn to make precise measurements with first class equipment. The specific skills learned are considered secondary. The lecture portion of the course is heavily based on principles and descriptive chemistry illustrates the concepts. This is impossible to teach without an introduction to some physics and math also. However, our students all take introductory calculus and the majority also take physics.	1	1	0	0	0	0	0	0	1	0
(m) All of the above. Stay in the middle as far as you can and as far as the student can.	0	0	0	0	1	2	0	0	1	0
(n) A modification of Choice (1). Basic chemical principles are highly essential and require enough descriptive chemistry to make these principles workable and desirable. Mathematical problems to illustrate or make the principles workable should certainly be stressed--especially those dealing with chemical equilibria and the mole concept.	0	0	0	0	1	2	0	0	1	0
(o) Limited principles followed by vigorous inorganic.	0	0	0	0	0	0	1	8	1	0
(p) Chemical principles with considerable descriptive chemistry of the elements serving as a supplement and illustration.	0	0	1	1	0	0	0	0	1	0

TABLE 17. (Continued)

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
5. Other (continued)										
(q) Choice (1) but present an experimental basis for chemical theory, not to treat descriptive material as simply illustrated of "principles."	0	0	1	1	0	0	0	0	1	0
(r) Lecture or in Choice (1) but lab should be almost exclusively qualitative in approach stressing physical properties, stochiometry, and structure.	0	0	1	1	0	0	0	0	1	0
(s) A course in chemical principles and properties, with the descriptive parts of the course used both to illustrate principles as the principles are taught and as illustrative of the principles when certain elements or types of compounds are discussed.	0	0	1	1	0	0	0	0	1	0
(t) A course in chemical principles with strong laboratory emphasis on descriptive and qualitative analysis (1st semester) and quantitative (including pH and electrochemistry) in 2nd semester.	0	0	2	2	0	0	0	0	2	0
(u) Choice (1) modified· some descriptive chemistry (even applications to industry) are of intrinsic value in addition to possible illustration of principles.	0	0	1	1	0	0	0	0	1	0

of specialized institution professors agree that time and cost have been essential factors that have prevented innovations in freshman chemistry. These statistics infer little information since the replies by the respondents from all categories show a general disagreement with the above statement (statement "6" of Table 16) as evidenced by only a 30 per cent agreement.

When the professors were asked to state an opinion on what they thought the introductory course should be, the response was multitudinous. However, Table 17 ("All Institutions" column, item "1") tabulations show a sufficient majority to say that a course in chemical principles with descriptive chemistry serving only to illustrate these concepts was warranted--the response ranging from a low of 64 per cent for liberal arts colleges to a high of 75 per cent for specialized institutions, with an average percent acceptance of 67 for all institutions surveyed.

Additional comments on Part II, Section 17 of the questionnaire reveal that some chemistry teachers are much concerned about the course content of the introductory courses currently offered in their institutions. Inherent within these additions is the plea to return to descriptive chemistry as shown by the fact that sixteen of the twenty-one additions specifically suggested an inclusion of more descriptive materials into the first-year chemistry course. Several comments stressed the point that the introductory course be improved. One professor suggested that, "Descriptive chemistry <u>must be brought back</u> to show how principles are derived." Another professor wrote: "I personally feel that more emphasis on theoretical topics is needed in most beginning college chemistry courses. However, I also believe that <u>descriptive facts</u> are <u>very</u> important for the research or teaching chemists. These 'descriptive topics'

TABLE 18. DESCRIPTION OF LABORATORY MANUAL OR TEXTBOOK CURRENTLY USED IN INTRODUCTORY COLLEGE CHEMISTRY

Description	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Staff prepared materials	12	14	13	16	0	0	2	16	27	12
2. Commercially prepared materials	24	29	22	28	6	14	4	33	56	26
3. Combination of (1) & (2)	44	52	40	51	34	81	6	50	124	58
4. Other										
(a) Choice (2) except lab manual is supplemented and text is supplemented by written handouts	1	1	0	0	0	0	0	0	1	0
(b) Choice (2) plus ditto experiment sheets	1	1	0	0	0	0	0	0	1	0
(c) Choices (1) and (2) plus Scientific American offprints	0	0	0	0	1	2	0	0	1	0
(d) Choose paperbacks over hard bounds	0	0	1	1	0	0	0	0	1	0
(e) Most of these are unsatisfying	0	0	1	1	0	0	0	0	1	0

are being sadly omitted from curriculums in many 'progressive' schools." The investigator believes that there is general agreement and consensus of a sufficient majority of the professors that an introductory college chemistry course offered in chemical principles and properties with descriptive parts of the course used both to illustrate principles and to show how principles are derived. A few institutions are offering special problem courses for weaker students and are also providing materials to assist these students. One institution offers a remedial course for students who have not had high school chemistry, however, any student may take this two semester hour course along with the regular course.

Description of Laboratory Manual and Textbook

The tabulations of data in Table 18 ("All Institutions" column, item "3") show that college professors indicated, by a 58 per cent approval, a possible acceptance of the use of a combination of staff prepared and commercially prepared materials for both lecture and laboratory. Junior college professors, by an 81 per cent response, indicated the practice of using a combination of staff and commercially prepared materials. The comments on other modifications as tabulated under the choice "other" in Table 18 are certainly enlightening. A few professors have written their own materials, one his own text, and two have written their own laboratory manuals. The Advisory Council on College Chemistry recommended that efforts be made to stimulate the preparation of a series of outlines, paperbacks, and suggestions for teaching dealing with some important topics not adequately treated in current textbooks. The survey findings has gained little information to indicate a direct response to the suggestions of the Advisory Council. The data collected do reflect

a slight trend to this effect. It would behoove these professors to share their educational endeavors with other professors by sending them to the Advisory Council on College Chemistry, Stanford University, California.

TABLE 19. NUMBER AND PERCENTAGE OF INSTITUTIONS INDICATING COURSE REVISIONS AND/OR NEW COURSE ADDITIONS

Type of Change	Univ.		Lib. Arts		Junior Colleges		Spec. Inst.		Total No. of Changes	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. New course or revision	26	31	20	25	11	26	4	33	61	28
2. Text or laboratory exercise change or revision	66	80	65	84	33	80	10	83	174	82

Course Revisions and/or Course Additions

The data in Tables 19 ("Type of Change" "1" and "2" in "Total" column) reveal that only 28 per cent of the responding institutions have added a new course or revised their present course yet the majority of the college chemistry professors during the past two years indicate displeasure with the current laboratory manuals and/or textbooks as evidenced by an 82 per cent indication in the "total" column of Table 19, item "2"; these institutions adhere to the same course outline. These data reveal that four out of five professors have made textbook and exercise changes in first-year college chemistry during the past two years while only three out of ten have either made course revisions or added new courses.

The additional comments from individual professors indicated a dissatisfaction with the present introductory course (30 professors wrote notes in the questionnaire margins and four enclosed personal letters and eight of these professors indicated that they were experimentating with various textbooks, including paperback supplements). Some of the professors remarked that they have yet to find a textbook they can agree is a satisfactory book. Other professors suggest a struggle with the course content especially in their attempts to answer questions related to such tasks as to the amount of descriptive work to include and whether or not to include thermodynamics. One professor had this to say regarding the status of the introductory college chemistry course:

> I'm retiring early because I've lost after 40 years all confidence in my judgement as to what to teach, how to do it, how much to expect of students, what performance deserves a passing grade. I'm too old to start over and recent years have produced increasing dissatisfaction with my work. I've kept on because recent staff and additions have seemed to have less competency than my own, but finally ---I've had it... This is not a criticism of administration, or criticism against our school. I've given up because my self-respect won't permit me to continue with the present frustrations.

Another professor added: "The lab manual is supplemented and the text is bad and is supplemented by handouts written by the instructor." In general, the trend is to do a limited number of experiments having a quantitative background and a small amount of descriptive work.

The data in Tables 20 and 20-A give a more vivid picture of the nature of textbook changes. The per cent response, as shown in Table 20, is in terms of the 174 respondents in the survey who indicated textbook changes and/or revisions. Three classifications of institutions (the exception is the specialized institution) in Table 20, item "1" indicated

TABLE 20. PERCENTAGE OF TEACHER RESPONSES TO QUESTIONS RELATING TO COURSE AND TEXTBOOK CHANGES

Types of Changes	Percentage of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y[a]	N[b]	U[c]	Y	N	U	Y	N	U	Y	N	U	Y	N	U
1. Have the content and program of instruction been considerably modified but the framework of the old course retained?	56	40	3	66	29	3	63	34	2	41	41	17	60	35	3
2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course?	62	36	1	57	40	2	56	41	2	50	50	0	58	39	1
3. Are you using an outline or syllabus which was prepared especially for the new course?	47	50	2	54	44	1	36	63	0	50	41	8	48	50	1
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units?	46	43	9	48	45	6	60	36	2	41	58	0	49	43	6
5. Do you expect more reading outside the text in the new or revised course than in the old course?	19	75	4	29	64	5	43	48	7	16	75	8	27	66	5
6. Is the work in the new or revised course independent of collaboration with physicists?	75	24	0	66	32	1	48	43	7	33	67	0	64	33	1

TABLE 20. (Continued)

Types of Changes	Percentage of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y	N	U	Y	N	U	Y	N	U	Y	N	U	Y	N	U
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory?	6	92	1	5	93	1	14	85	0	16	83	0	8	91	0
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course?	13	84	2	22	76	1	26	68	4	25	75	0	19	77	2
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access?	32	63	3	42	51	5	56	41	2	58	41	0	42	52	3
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?	28	65	5	31	66	2	31	58	9	33	67	0	30	64	4

[a]Y - Yes

[b]N - No

[c]U - Uncertain

that the content and program of instruction in general chemistry had been considerably modified but the outline of the former course retained. The data in Table 20 ("All Institutions" column, item "2") show that 58 per cent (a possible acceptance) of the professors who made textbook changes still rely mainly upon a single textbook and laboratory manual. The 48 per cent affirmative reply of all respondents to the question related to the preparation of a course outline or syllabus (Table 20, statement "3") indicates that liberal arts and university professors either rejected or do not have time to prepare a course outline or syllabus for a new introductory course. The implication is that the course authority, in general, is the textbook. The liberal arts and specialized institution professors, however, did indicate a possible acceptance of the responsibility of preparing a syllabus or course outline as evidenced by the 54 and 50 per cent affirmative replies, respectively (Table 20, item "3"). With respect to the question concerning the use of an outline or syllabus specifically prepared for a new course, the t-test score of 2.061 (Table 20-A, column "six," item "3") favors the liberal arts colleges over the junior colleges at the five per cent level of confidence.

The implication from the data in Table 20 ("All Institutions" column, statement "4") is a possible refusal of teaching the traditional topics of gases, liquids, and solids under a single topic rather than being discussed individually. The junior college professors conversely showed a possible acceptance of teaching these units separately, as evidenced by a 60 per cent affirmative reply to statement "four" in Table 20.

The professors from all institutions surveyed rejected the assignment of more outside reading in the new course as compared to the reading

required with the course which was replaced or with the former textbook, as shown by a 66 per cent negative reply to statement "5" in Table 20, "All Institutions" column. AC_3[178] recommended that efforts be made to stimulate the preparation of a series of outline, paperbacks for teaching, at the first-year college chemistry level, dealing with some important topics not adequately treated in current texts. Although some of these topics have been published by the <u>Journal of Chemical Education</u> and several major publishing companies, the above data indicate little or no use of the said materials.

TABLE 20-A. T-TEST OF SIGNIFICANCE

Topic	J.C. vs. Spec.	L.A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J.C.	Univ. vs. L.A.	L.A. vs. J.C.
Degree of Freedom	51	87	92	121	157	116
Statements Concerning Textbook Changes (See Table 20)	t-test (1)	(2)	(3)	(4)	(5)	(6)
1	0.703	0.406	0.922	0.332	1.152	0.655
2	0.610	0.732	0.922	0.366	0.275	0.129
3	1.699	0.589	0.808	1.552	0.548	2.061*
4	1.373	1.031	1.217	0.000	0.477	0.423
5	1.184	0.368	0.150	2.376*	1.026	1.549
6	1.509	2.292*	3.074*	1.255	0.917	0.513
7	0.166	0.868	0.785	0.945	0.146	1.062
8	0.624	0.022	0.479	1.911	0.878	1.204
9	0.147	0.276	1.039	1.932	1.403	0.684
10	0.837	0.182	0.414	0.771	0.536	1.296

*Significant at the five percent level of confidence.

[178] Haenisch, "Content of Introductory College Chemistry," p. 21.

The only college classification to indicate a collaboration with physicists in the preparation of a course or the selection of a new textbook (Table 20, statement "6") was the specialized institution with a 67 per cent negative reply to the statement, "Is the work in the new or revised course independent of collaboration with physicists?" The t-test scores of 2.292 and 3.074 in Table 20-A (Columns "2" and "3," statement "six") support this observation and show this collaboration of chemist and physicists to be significant at the five per cent level of confidence when the mean of the responses of the specialized institutions are compared with the mean responses of the liberal arts colleges. These t-tests show that the only category which either requested or used the assistance of physicists in the preparation of a new first-year chemistry course was the specialized institutions. All institutions rejected the practice of stating course objectives and the ensuing preparation of tests or other methods of evaluating whether these objectives have been achieved, as reflected by a 42 per cent and a 19 per cent affirmative reply to statements "nine" and "eight" in Table 20, "All Institutions" column. Of the 42 per cent that accepted the stated objectives (Table 20, "All Institutions" column, item "9") less than half (statement "8" shows a 19 per cent response) of these established methods to ascertain achievement of these goals. A closer examination of the data in Table 20, statement "9," indicate a possible acceptance of the responsibility of stating goals by junior colleges and specialized institutions as evidence by a 56 per cent and a 58 per cent affirmative response, respectively. Less than half of these professors, however, have designed methods to evaluate attainment of these stated goals as evidenced by a 26 and 25 per cent

reply to statement "8."

The investigator believes that the way to future progress still seems to lie in more thought on the part of college professors about goals and purposes. The data in Table 20 (statement "nine") reveal that the majority of the junior college and specialized institution professors have stated objectives and logically, it seems that since a large number of these institution's students transfer to liberal arts colleges and universities, logic seems to dictate that these latter institutions of higher learning need to state goals and devise evaluation schemes. The survey data also reflect another pedagogical weakness: although textbook changes have been made, the previously stated course objectives have been changed very little, if any, as evidenced in Table 20 (statement "ten") by a 64 per cent negative reply to the question, "Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?" The data in Tables 19 and 20 reinforce the statements of Strong and Young[179] which implied an urgent need for reorganized textbooks and courses, and a vehement request that the very best efforts be expended in the preparation of general chemistry textbooks.

Pre-laboratory Instruction

Pre-laboratory instruction is essential to a successful laboratory program and might replace the usual detailed laboratory instructions.[180]

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[179] See pp. 33 and 35 of this survey.

[180] Modern Teaching Aids for College Chemistry. Los Angeles, California: Advisory Council on College Chemistry, 1966, pp. 1-7.

TABLE 21. TYPE OF PRE-LABORATORY INSTRUCTION GIVEN TO INTRODUCTORY COLLEGE CHEMISTRY STUDENTS

Types of Instruction	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Students are expected to have read directions.	73	89	72	93	38	92	11	91	194	91
2. Students are assigned supplementary readings other than laboratory manual directions.	9	10	11	14	9	21	3	25	32	15
3. A pre-laboratory drill assures that students have read directions.	16	19	9	11	7	17	2	16	34	16
4. A pre-laboratory quiz assures that students have read directions.	16	19	13	16	5	12	3	25	37	17
5. A pre-laboratory quiz assures that students have read supplementary readings.	1	1	1	1	0	0	0	0	2	0
6. A pre-laboratory quiz assures that students have worked the drill.	1	1	2	2	2	4	0	0	5	2
7. The experiment is demonstrated.	4	4	7	9	9	21	0	0	20	9
8. Procedure is discussed.	64	78	71	92	32	78	11	91	178	83
9. The theoretical basis of the experiment is discussed.	57	69	64	83	32	78	10	83	163	76
10. Questions are answered.	59	71	64	83	32	78	10	83	165	77
11. Special emphases and different points are elucidated.	55	67	55	71	29	70	9	75	148	69
12. Other										
(a) Preliminary exercises are filled out by students prior to coming to lab.	1	1	0	0	0	0	0	0	1	0
(b) Preliminary questionnaire is filled out by student before lab (at his convenience) to assure that students have read directions.	1	1	0	0	0	0	0	0	1	0
(c) Students are given exams (written) after completion of experiment.	2	2	0	0	0	0	0	0	2	0
(d) Instructions vary—depend on type and difficulty of experiment.	1	1	0	0	0	0	0	0	1	0
(e) Experimental set-ups with emphasis on safety are shown.	1	1	0	0	0	0	0	0	1	0
(f) Experiment outlined in lab notebook prior to formal lab.	0	0	1	1	0	0	0	0	1	0
(g) Student must write a detailed procedure in lab notebook before coming to lab.	0	0	1	1	0	0	0	0	1	0

TABLE 21. (Continued)

Types of Instruction	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
12. Other (continued)										
(h) Safety precautions are given.	0	0	2	2	1	2	0	0	3	1
(i) Theory is covered in lecture in advance of lab work.	0	0	1	1	0	0	0	0	1	0
(j) Do not believe in pre-labs.	0	0	1	1	0	0	0	0	1	0
(k) Occasional pre-lab quiz.	0	0	0	0	1	2	0	0	1	0
(l) Combination of choices (a) and (c).	0	0	0	0	1	2	0	0	1	0
(m) The student works from directions he has formulated from manual and supplementary readings.	0	0	0	0	1	2	0	0	1	0
(n) Enough is discussed so that purpose is clear and technique understood.	0	0	0	0	1	2	0	0	1	0
(o) TV tapes covering equipment and setup shown last 5 minutes of class prior to lab.	0	0	0	0	0	0	1	8	1	0

Time should be made available for a student to try to solve an experimental problem, discover an error in the procedure or judgment, and then try again. The Advisory Council on College Chemistry has developed and discussed the feasibility of using television tapes, film loops, and computer assisted instruction (CAI) to supplement lecture and laboratory.[181] Some excellent television tapes and film loops are available which illustrate specific laboratory techniques or provide visual instructions for operating or understanding the principles of specific instruments. Films are also available which present the student with experimental data which he can then interpret and which permit him to draw conclusions. In addition, pre-labs are excellent for safety precautions, experimental design discussion, and experimental technique descriptions.

Use of Pre-laboratory Instruction

The data in Table 21, statement "1," disclose, if valid, a disturbing lack of responsibility on the part of a few chemistry educators. The data (the total number of institutions in each category minus the value listed in Table 21, statement "1,"--Types of Instruction) showed that 11 per cent of the university professors, 7 per cent of the liberal arts professors, 8 per cent of the junior college professors, and 9 per cent of the specialized institution professors did not expect students to have read directions prior to laboratory. Perhaps the answer lies in the observation that some institutions do not offer laboratory. This observation does raise several questions, however. Assuming the data to be correct, does this indicate a lack of responsibility on part of the

[181] Ibid., p. 11.

professor, or does this indicate that students are designing their own experiments? One professor emphatically stated that he did not believe in pre-labs. Three professors indicated post-laboratory examinations.

The data in Table 21 disclose that the typical pre-laboratory, other than leaving the responsibility up to the student himself, revolves around the instructor dispensing information to the student. The four most generally accepted pre-laboratory instructions as evidenced by a 69, 76, 77, and 83 per cent indicated usage ("All Institutions" column, Table 21) of "Types of Instruction," in the ascending order from least favored to more favored, are: (1) special emphases and different points are elucidated (item "11"), (2) the theoretical basis of the experiment is discussed (item "9"), (3) questions are answered (item "10"), and (4) procedure is discussed (item "8"). A total of 26 Types of Instruction including 15 under the choice "other" were discussed.

TABLE 21-A. T-TEST OF SIGNIFICANCE

Topic	J.C. vs. Spec.	L.A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J.C.	Univ. vs. L.A.	L.A. vs. J.C.
Degrees of Freedom	51	87	92	121	157	116
Pre-lab Instruction (See Table 21)	(1)	(2)	(3)	(4)	(5)	(6)
1	0.113	0.231	0.272	0.636	0.987	0.167
2	0.213	0.929	1.339	1.613	0.622	1.043
3	0.032	0.476	0.229	0.323	1.345	0.802
4	1.057	0.666	0.433	1.005	0.424	0.664
5	0.000	0.390	0.378	0.701	0.044	0.723
6	0.760	0.556	0.378	1.225	0.631	0.641
7	1.780	1.076	0.771	2.953*	1.037	1.939
8	1.035	0.063	1.083	0.000	2.511*	2.204*
9	0.383	0.018	0.974	0.986	2.011*	0.663
10	0.383	0.018	0.820	0.716	1.675	0.663
11	0.278	0.250	0.540	0.405	0.588	0.078
12	0.654	0.083	0.153	1.355	0.142	1.406

*Significant at the five percent level of confidence.

The t-test score of 2.953 in Table 21-A, statement "7" and the t-test scores of 2.511 and 2.204 (statement "8") and 2.011 (statement "9") show the following differences in pre-laboratory instructional procedures between the different college classifications: (1) the junior colleges place more emphasis upon demonstrations as a pre-lab procedure as indicated by a significant difference at the five per cent level of confidence (t-test score = 2.953) when compared with universities, (2) the liberal arts colleges favored more discussion on procedure and the theoretical basis of the experiment when compared with universities at the five per cent level of confidence (t-test scores = 2.511 and 2.204), and (3) a similar significant difference at the five per cent level of confidence (t-test score = 2.011) was noted between the liberal arts colleges and junior colleges, in favor of the liberal arts colleges, in regard statement "8" of Table 21--the discussion of procedure.

One professor directed attention to the use of television tapes covering equipment and setup prior to laboratory work. The availability of audiovisual educational media specifically designed by AC_3 members (Table 21 data show only one respondent using television tapes while none indicated the use of film loops) for the use of film loops was lacking. The answer probably is reflected in that the use of television tapes for pre-labs came considerably before the formation of AC_3 and is probably only superior to demonstration where large numbers are involved unless the student is able to review the tapes. One college professor in the survey remarked:

> Visual aids are overemphasized. They are good but tend to oversimplify.

This remark tends to support the above statement in relation to the low usage of audiovisual media in pre-laboratory instruction.

Procedure for Handling Experimental Data

The spirit of science cannot be imparted by words alone since the nature of a scientific enterprise is shown most clearly by carefully thought-out laboratory work. In order for laboratory work to be successful an experiment must be meaningful and data must be collected and interpreted. "Data are the information which is derived from an experiment or observation."[182] and in order for data to be interpreted, data must be available for inspection and this necessitates instruction in the proper use of recording data. According to the Advisory Council on College Chemistry, "fill-in-the-blank" reports are much less valuable than keeping a notebook or journal, or writing reports in the style of articles presented in scientific publications.[183] Procedures used by the different institutions as to the method(s) by which their students handle data (Table 22) show a great deal of variability. There seems to be no one way of handling data (nine different methods were listed). The most typical method, as indicated by a 41, 46, 34, and 25 per cent response to item "3" in Table 22 by universities, liberal arts colleges, junior colleges, and specialized institutions, in the order listed, is to have students record data in blank notebooks. The 41 per cent response by all institutions indicating some adherence to this practice, however, there is insufficient evidence to warrant this as a typical

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[182] John W. Renner and William B. Ragan. Teaching Science in the Elementary School. New York: Harper and Row, 1968, p. 163.

[183] Haenisch, "Experimental Curricula in Chemistry," pp. 21-22.

TABLE 22. PROCEDURES USED BY INTRODUCTORY CHEMISTRY STUDENTS FOR HANDLING EXPERIMENTAL DATA

Handling Procedures	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Data are recorded in duplicate by use of carbon paper.	7	8	3	3	2	4	2	16	14	6
2. Data are recorded on blank separate sheets.	7	8	13	16	8	20	1	8	28	13
3. Data are recorded in blank notebooks.	34	41	36	46	14	34	3	25	87	41
4. Data are recorded on special printed forms you provide separately.	10	12	9	11	6	14	2	16	27	12
5. Other										
(a) Data are recorded in space provided in laboratory manual.	17[a]	21	11	14	6	15	4	33	38	18
(b) General formal laboratory reports are required of students each year. The rest of the time, data are handed in on 3" x 5" cards.	0	0	2	3	0	0	0	0	2	0
(c) Qualitative analysis data are recorded in student notebooks.	0	0	1	1	0	0	0	0	1	0
(d) Data sheets are signed by the instructor who keeps one copy for later reference.	0	0	0	0	1	2	0	0	1	0
(e) Special report is written and turned in for grading.	0	0	0	0	1	2	0	0	1	0

[a]One respondent indicated a departure from standard manual soon.

practice by college professors; this is one of the data recording devices suggested by the Advisory Council on College Chemistry. The data in Table 22, item "5-a" show 18 per cent of all institutions surveyed (21 per cent of universities and 33 per cent of the specialized institutions) still allow students to record data in the spaces provided in the laboratory manual—apparently the old cook book is obsolete but is still being used.

Recording of Laboratory Data

The most important function of a laboratory report is to focus the student's attention on the interpretation of data and the significance of results obtained from the experiment. Many of the new experiments are designed to permit real freedom of thought on the part of the student and can be written up in a project form.[184] The purpose, procedure, experimental data (in a form designed by the student), conclusion, and, most important, an analysis of the results can be written in concise form. Students need the experience of making interpretations of data, instead of having college professors make interpretations for them. The first prerequisite in data interpretation is keeping accurate and complete records.

There is no question that grading of the project-type of report is time consuming. However, the project-type (research-type) of report can help to develop the student's report writing ability and lends itself well to the type of experiments and reporting which require some creative

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[184] A project form is a research-type report which is prepared individually by the student and patterned after a research notebook.

TABLE 23. TYPE OF REPORTING EXPECTED FROM INTRODUCTORY CHEMISTRY STUDENTS

Type of Report	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Fill in data and results on printed sheets.	60	73	42	54	23	55	4	33	129	61
2. Students design their own report sheets.	22	26	26	33	10	24	8	66	66	31
3. Full reports (essay form).	10	12	11	14	12	29	3	25	36	16
4. Sample calculations only.	19	23	28	36	10	24	3	25	60	28
5. Full calculations.	43	52	37	48	22	53	7	58	109	51
6. Duplicate raw data sheets (carbon paper record).	7	8	3	3	3	7	4	33	17	8
7. Supplementary questions are answered in the laboratory.	31	37	38	49	14	34	7	58	90	42
8. Graphs from data in the laboratory.	48	58	49	63	28	68	5	41	130	61
9. Other										
(a) Combinations of several methods are used (depends on nature of experiment.)	0	0	2	2	0	0	0	0	2	1
(b) Result only on report sheet. Data and calculations checked in lab notebooks.	0	0	1	1	0	0	0	0	1	0
(c) Students write up the experimental results in proper scientific manner.	0	0	2	2	1	2	0	0	3	1
(d) Students keep notebooks for data, observation, calculations, and a paragraph for conclusions.	8	10	4	5	0	0	0	0	12	6
(e) Full report (3) plus assigned questions (essay).	0	0	2	2	0	0	0	0	2	1
(f) Answer sheets in lab manual including questions.	1	1	2	2	0	0	0	0	3	1
(g) Many questions on examinations are based on lab work.	0	0	1	1	0	0	0	0	1	0
(h) Signed raw data sheets.	0	0	0	0	0	0	1	8	1	0
(i) Full report taken from lab notes.	0	0	0	0	1	2	0	0	1	0
(j) Sometimes the student designs own report sheet.	0	0	1	1	1	2	0	0	2	1
(k) Outline form in notebook.	0	0	0	0	1	2	0	0	1	0
(l) Full report (sometimes).	0	0	0	0	1	2	0	0	1	0
(m) Report Cards.	0	0	0	0	1	2	0	0	1	0
(n) Unknown and unknown analysis.	0	0	2	2	0	0	0	0	2	1

TABLE 23. (Continued)

Type of Report	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
9. Other (continued)										
(o) Students have one week to complete report from data collected in lab.	0	0	0	0	1	2	0	0	1	0
(p) Reactions and equations.	1	1	0	0	0	0	0	0	1	0
(q) Write complete reports in style of journal articles.	1	1	0	0	0	0	0	0	1	0
(r) Discussions on various selected aspects of the experiment (outside class).	1	1	0	0	0	0	0	0	1	0

thinking on part of the student. AC_3 has encouraged that instead of the "fill-in-and-detach" type of laboratory texts and manuals, professors require students to use the research-type reports, prepared individually and patterned after a research-type notebook. Perhaps the logical answer to the time consuming evaluation of the research type report is a reasonable student per instructor ratio or an increase in the number of capable, qualified student assistants. No one will deny that the use of the research type report is of considerable value, but it is time consuming and therefore limits the number of experiments that can be done. A compromise between using other methods of reporting in part of the first course and the report written in the research manner in other parts of the course, allows both more lengthy experiments to be undertaken and experiences to be gained in report writing as well.

Type of Reporting Expected by Institutions in the Survey

The interpretation of the data in Table 23 allowed the investigator to conclude that the most typical type of data reporting expected from first-year college chemistry students is to have them fill-in-data and results on printed sheets as shown by a 61 per cent response to statement "1" in "Total" column. An equivalent number of professors expect graphs as evidenced from the data (statement "8") and the third preference is full calculations (a 51 per cent positive response to item "5"). The 61 per cent response (statement "1," Table 23) of all professors to the previously mentioned fill-in-data reporting practices indicates a possible acceptance of this practice. The data from the survey, as shown in Table 23, statement "7" reveal that 42 per cent of the respondents request answers to supplementary questions on printed sheets. The

specialized institutions, by a 66 per cent response (Table 23, statement "2") allow their students to design their own report sheets. Full essay reports (item "3") were used by 16 per cent of all institutions (the junior colleges showing a high of 33 per cent) indicating a rejection of the Advisory Council on College Chemistry plea for research-type reports.[185] Here, the investigator suggests that any first-year chemistry course consists of a series of compromises. One of these is between the time the student spends in experimentation, calculation, interpretation, and report writing. By using methods intended to shorten the time spent on report writing more time is available for the other activities. This should not be carried to the extreme, however. Some experiments should be written by the research-type report method.

TABLE 23-A. T-TEST OF SIGNIFICANCE

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
Laboratory Reports (See Table 23)	(1)	(2)	t-test (3)	(4)	(5)	(6)
1	1.408	1.351	1.667	0.703	1.323	0.396
2	2.818*	2.192*	2.821*	0.286	0.943	1.041
3	0.278	0.929	1.180	2.341*	0.384	1.954
4	0.042	0.754	0.137	0.148	1.818	1.313
5	0.275	0.649	0.374	0.126	0.546	0.571
6	2.359*	3.664*	2.511*	0.230	1.195	0.793
7	1.481	0.567	1.337	0.391	1.459	1.574
8	1.653	1.433	1.084	1.037	0.652	0.498
9	0.548	0.446	0.580	0.000	0.297	0.245

*Significant at the five per cent level of confidence.

[185] "Instruction in General Chemistry and Expanding Student Population," p. 11.

The t-test scores of 2.818, 2.192, and 2.821 in Table 23-A, columns "one," "two," and "three," laboratory reports, statement "1," show the practice of students designing their own report sheets favored the specialized institutions over the junior colleges, liberal arts colleges, and the universities at the five per cent level of confidence. The t-test scores with respect to statement "6"--duplicate raw data sheets (carbon paper record)--under columns "1," "2," and "3" of Table 23-A, are 2.359, 3.664, and 2.511. The t-test scores for both statements "1" and "6" show, at the five per cent level of confidence, that a higher per cent of the specialized institutions students design their own report sheets and use raw data sheets with carbon records than do the students from the other three categories.

The professors from all the institutions surveyed, as shown in Table 23, listed a total of 26 different methods used by students to record data. What do these data imply? Are there really this many ways of recording experimental data which are educational beneficial to the student?

Useful suggestions were also offered in the additional comments by professors and several practices were suggested. Two such practices were the requiring of students to keep data notebooks and to duplicate raw data sheets for evaluation by the laboratory instructor.

The response to Part I, sections 10, 11, 12, 13, and 14 of the questionnaire indicates that the majority of the chemistry professors answering the questions related to chemistry laboratory believe the present introductory college chemistry laboratory course to be unsatisfactory for all students. They believe that the regular laboratory course could be significantly improved by scrutiny in designing and selection

of laboratory experiences as evidenced by a majority of responding institutions using a combination of staff prepared and commercially prepared materials, but some also believe that modification of the regular course may lead to superficial results for the specializing students. The group as a whole seem quite definitely opposed to the deletion of first-year college chemistry laboratory from the college curriculum. The professors also indicated some effort in the development of new experiments and expect their students to take part in designing his own experiments. A few of the professors indicated the use of unknowns and unknown analysis. One college indicated the use of a class-project type experiments. Here small groups of students (30 or less) are each assigned a different aspect of the problem (different masses are assigned in a compound synthesis). The use of experimental techniques and the stressing of safety was also emphasized.

The data from the responses to the questions related to the laboratory phase of introductory college chemistry imply a need for standards regarding the selection of laboratory experiments and agreement on the methods to be used in recording data.

Type of Honors Courses Offered

Observation of the data in Table 24 shows that 41 colleges offer honors courses with a minimum of 23 different course descriptions, the more typical one being the a course in chemical principles with descriptive chemistry. Part A of Table 24 shows the variety of courses offered; the inference from these data is that a single honors course does not

TABLE 24. TYPE OF HONORS COURSES OFFERED

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
A. Description of Courses					
1. One which omits descriptive inorganic and schematic scheme of analysis.	2	0	1	1	4
2. A one semester course followed by thermodynamics.	0	0	0	0	0
3. A course in chemical principles with descriptive chemistry.	10	3	2	0	15
4. A course comprising largely organic chemistry.	0	0	0	0	0
5. A combined chemistry-physics course.	1	0	0	1	2
6. A course in crystal structure.	0	0	0	0	0
7. Other	11	5	3	1	20
a. One year course plus quantitative analysis.	1	0	0	0	1
b. A one-credit, one semester course to fill in deficiencies, followed by qualitative and descriptive course.	1	0	0	0	1
c. A 2-quarter course sequence covering one year work in a regular course.	1	0	0	0	1
d. All topics covered in more depth and detail than in the regular course.	1	0	0	0	1
e. Advanced General and Kinetics and Thermodynamics, Mechanisms.	1	0	0	0	1
f. The regular course with a different laboratory and substitution material.	1	0	0	0	1
g. Chemical Principles (one semester).	1	0	1	0	2
h. Course in chemical principles with strong emphasis on thermodynamics and quantam chemistry; NO lab work.	0	0	0	1	1
i. Largely elementary physical chemistry.	1	0	0	0	1
j. Principles, Descriptive, Inorganic and Quantitative Analysis.	1	0	0	0	1
k. A second semester course emphasizing equilibrium and thermodynamics.	1	1	0	0	2
l. A course in chemical principles with laboratory emphasis on analytical techniques.	1	0	1	0	2

TABLE 24. (Continued)

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
7. Other (continued)					
m. Current Scientific Development.	0	0	1	0	1
n. A course in chemical principles with a lab consisting of qualitative analysis, biochemistry, and quantitative analysis.	0	1	0	0	1
o. Descriptive Chemical Research; Qualitative Analysis; Chemical Principles; Quantitative Analysis.	0	1	0	0	1
p. A course which integrates analytical chemistry and general inorganic chemistry.	0	1	0	0	1
q. A rigorous contact with general chemistry--quite mathematical.	0	1	0	0	1
B. Methods for Selecting Students					
1. Placement Examination.	7	1	2	1	11
2. College Board Examinations.	7	1	1	0	9
3. Special Examinations.	4	0	0	0	4
4. High School Science Background.	10	2	5	0	17
5. High School Record.	10	3	5	0	18
6. American College Testing Program.	4	1	1	0	6
7. American Chemical Society Exam.	1	0	3	1	5
8. ACT Grade in Mathematics.	2	0	2	0	4
9. High School Chemistry Grade.	6	3	4	0	13
10. Other	10	6	3	1	20
a. Local test given after choice (1)	1	0	0	0	1
b. Special formula worked out by Vanderbilt Testing Service, based on ability in course.	1	0	0	0	1
c. Free choice of eligible students (student enthusiasm is vital to make program effective).	1	0	0	0	1
d. Must be enrolled in calculus course.	1	0	0	0	1
e. Vocational interest.	1	2	0	0	3
f. Interview.	1	0	0	0	1
g. Purely elective.	0	1	0	0	1
h. Placement exam in math and chemistry, prepared by the Department.	1	0	0	0	1

TABLE 24. (Continued)

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
10. Other (continued)					
i. Chemistry majors and/or chemical engineers—few deleted by test.	2	2	0	0	4
j. First semester record in chemistry.	1	0	1	0	2
k. Standing in freshman math.	0	0	0	1	1
l. Two years of algebra.	0	0	1	0	1
m. Instructors select on basis of past performance of student.	0	1	1	0	2
C. Suitability of "available" textbooks					
1. Suitable textbooks and laboratory manuals are available.	12	0	5	0	17
2. None of the existing textbooks or laboratory manuals suit our purpose.	4	2	1	1	8
3. Other	11	4	0	1	16
a. Have written own textbook or lab manual.	3	2	0	0	5
b. Choose to deviate from lab manuals because of greater freedom of opportunity to test items for main course. Therefore, NO manual could omit or fit purposes.	1	0	0	0	1
c. Suitable text but no suitable manual.	3	1	0	1	5
d. Barely suitable text—no lab manual.	1	0	0	0	1
e. Suitable textbooks and paperbacks are available.	1	0	0	0	1
f. Develop lab experiments for second semester.	1	0	0	0	1
g. Would like a lab manual with more quantitative experiments.	1	0	0	0	1
h. Use three texts.	0	1	0	0	1

meet the needs of all colleges and universities. Part "B" of Table 24--Methods for Selecting Students--confirms this inference by disclosing that there are almost as many ways of selecting students for honors courses as are variety of honors courses. The more popular methods were: (1) placement exams, (2) high school science background, (3) high school record, and (4) high school chemistry grade.

There was insufficient evidence to detect a trend with relation to the suitability of "available" textbooks specifically designed for the honors course, however, the majority of the university professors who responded (Part "C" of Table 24) felt that suitable textbooks and laboratory manuals are available. The reader is directed to Part C of Table 24 for an analysis of some of the practices and suggestions of individual professors.

Challenging the Superior Student

The failure of a college to challenge the fraction of each freshman class that is superior is a luxury that society and colleges cannot afford. Not to require the best efforts of the better students in order that the average students can get by is an injustice to both groups of students and our collective future. At least four types of programs for the superior students are now in use: (1) honors courses, (2) seminars, (3) advanced placement, and (4) independent study.

A small percentage of all institutions surveyed are using independent study, conference study, advanced placement, special projects, and several other methods to challenge superior students. The nature of these challenges is shown in the tabulations of Table 25 (Parts "B," "C," "D," "E," and "F"). Many reasons were given for not specifically

TABLE 25. CHALLENGES TO SUPERIOR STUDENTS

Type of Course Offered	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
A. No provisions made, because										
1. No interest.	2	2	1	1	4	9	0	0	7	3
2. Lack of student time.	12	14	15	19	8	19	2	16	37	17
3. Lack of professor time.	17	20	23	29	13	31	3	23	56	26
4. Lack of facilities.	9	11	8	10	8	19	4	33	29	14
5. Do not have, but are interested.	11	13	25	32	10	24	3	23	49	23
6. Other	15	18	7	9	5	12	1	8	28	13
a. Lack of opportunity to become involved in undergraduate research.	1	1	0	0	0	0	0	0	1	0
b. High school chemistry is a very "elastic" course and no definite measure of achievement is evident in many cases.	1	1	0	0	0	0	0	0	1	0
c. Keep the regular course at a level of difficulty that even the superior students are challenged.	5	6	5	6	0	0	0	0	10	5
d. Present an interesting, honest course.	1	1	0	0	0	0	0	0	1	0
e. Offer more than one introductory course.	1	1	0	0	0	0	1	8	2	1
f. Few students of that caliber.	1	1	0	0	3	7	0	0	4	2
g. There is no such thing as "superior" students or "special" talent.	0	0	0	0	1	2	0	0	1	0
h. Special sections and assignments.	1	1	0	0	0	0	0	0	1	0
i. Few students want <u>additional</u> study.	1	1	1	1	0	0	0	0	2	1
j. Freshmen are very busy and the regular course is demanding.	1	1	0	0	0	0	0	0	1	0
k. Students are not good enough to handle additional independent work.	2	2	0	0	1	2	0	0	3	1
l. Do not introduce research to freshmen; do not regard this as advisable or sound education.	0	0	1	1	0	0	0	0	1	0

B. Independent Study: (The student carries on a study of basic research under the direction of a faculty member and prepares a paper on his work in the manner of a journal article). The nature of this independent study is a

TABLE 25. (Continued)

Type of Course Offered	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
B. Independent Study: (continued)										
1. Special laboratory project.	18	21	13	16	7	17	2	16	40	18
2. Special problem in qualitative analysis.	1	1	8	10	1	2	1	8	11	5
3. Special problem selected by the individual student.	8	9	6	7	8	20	2	16	24	11
4. Special problem selected by the chemistry department.	6	7	9	11	2	4	2	16	19	8
5. Do not have, but are interested.	12	14	16	20	12	29	3	25	43	20
6. No interest.	3	3	5	6	1	2	0	0	9	4
7. Other	2	2	4	5	3	7	0	0	9	4
a. Challenge them to pace the class.	0	0	1	1	0	0	0	0	1	0
b. Small investigations.	0	0	1	1	0	0	0	0	1	0
c. Student may choose a more difficult experiment to illustrate a chemical principle.	0	0	1	1	0	0	0	0	1	0
d. Students are encouraged to persue AC_3 published experiments.	0	0	1	1	0	0	0	0	1	0
e. Separate course.	0	0	0	0	1	2	0	0	1	0
f. Assist students with research projects and require writings.	0	0	0	0	1	2	0	0	1	0
g. ACS Essay Contest.	0	0	0	0	1	2	0	0	1	0
h. Student is given supplementary reading.	2	2	0	0	0	0	0	0	2	1
C. Conference Study or Conference Sessions: (Informal meetings on a variety of topics - freshman presentation).										
1. Seminar.	6	7	8	10	3	7	1	8	18	8
2. Assist professors or graduate students in preparing papers to be presented at seminars.	0	0	2	2	0	0	0	0	2	1
3. Other	2	2	6	7	1	2	0	0	9	4
a. Short report required or outside reading.	0	0	1	1	0	0	0	0	1	0
b. Problem sessions and seminars available.	0	0	1	1	0	0	0	0	1	0
c. Freshmen invited to regular junior-senior seminar.	1	1	2	2	0	0	0	0	3	1
d. Informal conferences - open for conferences at vacant periods.	0	0	2	2	0	0	0	0	2	1

TABLE 25. (Continued)

Type of Course Offered	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
3. Other (continued)										
e. Informal discussions with chemistry majors.	0	0	0	0	1	2	0	0	1	0
f. Experimenting with tutorial system for the top 5%--1 hour conference each week. Use these students as tutor for all other students. A tutor is available (about 50 students) every day at several different hours to assist the weak students.	1	1	0	0	0	0	0	0	1	0
D. Advanced Placement										
1. Passing an exam equivalent to general chemistry "final" (oral and/or written).	7	9	0	0	2	5	0	0	9	4
2. Advanced Placement Exam.	4	4	3	4	4	9	1	8	12	6
3. CEEB Score.	3	4	0	0	0	0	0	0	3	1
4. ACS High School Exam. (Greater than 70%).	1	1	0	0	0	0	0	0	1	0
5. Entrance Exam Score.	2	2	0	0	0	0	0	0	2	1
6. Good Academic Background (high school).	5	6	0	0	0	0	0	0	5	2
7. Good Academic Background (college at end of 1st quarter or end of 1st semester).	0	0	0	0	1	2	1	8	2	1
8. SAT math, high school chemistry.	0	0	0	0	1	2	0	0	1	0
E. Special Projects										
1. Number	17	21	15	20	9	22	2	17	43	20
2. Percent Devoted to Project										
a. 1-4%	1	--	0	--	3	--	0	--	4	--
b. 5-8%	5	--	2	--	1	--	0	--	8	--
c. 9% or higher	11	--	13	--	5	--	2	--	31	--
F. Other Methods Used to Challenge Students										
1. Avoid duplication with high school lab.	1	1	0	0	0	0	0	0	1	0
2. Talented students are taught to program chemical problems for computer and then run the programs.	1	1	0	0	0	0	0	0	1	0

TABLE 25. (Continued)

Type of Course Offered	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
3. Undergraduate research program is open to such freshmen; projects are individual and at least at master's level.	1	1	0	0	0	0	0	0	1	0
4. Superior students are encouraged to do research on a regular problem of interest to a faculty member.	2	2	0	0	0	0	0	0	2	1
5. Assign students to paper grading and general assisting.	1	1	0	0	0	0	0	0	1	0
6. Pay student assistants in research labs sometimes on independent project.	1	1	0	0	0	0	0	0	1	0
7. Limited special projects.	1	1	0	0	0	0	0	0	1	0
8. Optional recitation sessions.	1	1	0	0	0	0	0	0	1	0
9. First semester laboratory is qualitative; second semester is quantitative.	1	1	0	0	0	0	0	0	1	0

designing courses to challenge the superior student. Part A of Table 25 gives an excellent picture of the negative response to a challenge to superior students, the more popular one being the lack of professor time. One respondent believes that there is no such thing as "superior" students or "special" talent; in fact, he stated that the well-prepared, capable student is a myth. Some colleges, however, are providing a variety of methods to challenge superior or talented students. One noteworthy method was the placement of students by examination in the second semester of the first-year course or in an upper level chemistry course. One professor took issue with the provision of a challenge to high ability students by stating, "Our work is demanding enough to challenge the best. We do not introduce research to freshmen. We do not regard this as advisable or sound education."

Objectives and Aims of Introductory College Chemistry

A list of 24 possible objectives of first-year college chemistry including a space under the title "other" for additions was assembled from many sources.[186] To bring forth any differences between the opinions of the respondents, the 210 college professors from a total of 212 institutions in the four college categories, the replies are tabulated under five headings in Tables 26 and 27. The results are compiled in terms of percentages and under the headings of "very important," "some importance," and "not at all important." In arranging and phrasing the

[186] Objectives of first-year college chemistry were taken from articles in The Journal of Chemical Education (listed in the "periodical" section of the Bibliography), the publications of the Advisory Council on College Chemistry (listed in the "bulletin" section of the Bibliography) and from the objectives listed in the "foreword" of many current chemistry textbooks and laboratory manuals.

TABLE 26. OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
1. Show the relationship of chemistry to other sciences.	41	37	2	34	38	3	27	14	0	9	3	0	111	92	5
2. Help the student to understand the nature of matter and its transformations.	75	5	0	72	4	1	38	3	0	12	0	0	197	12	1
3. Develop the ability to do critical thinking.	72	8	0	73	4	0	40	1	0	12	0	0	197	13	0
4. Make students familiar with the facts, principles, and concepts of chemistry.	71	9	0	71	6	0	38	3	0	8	4	0	188	22	0
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	25	53	2	23	52	2	18	22	1	3	8	1	69	135	6
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	26	46	8	26	43	8	16	21	4	3	6	3	71	116	23
7. Give students an idea of the importance and significance of chemistry in our national life.	17	53	10	20	48	9	21	17	3	4	6	2	62	124	24
8. Development of specific interests, habits, and abilities which should be contributed to by <u>all courses</u> in science.	45	32	3	34	31	9	22	8	1	8	4	0	109	85	13

TABLE 26. (Continued)

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	3	41	36	4	38	35	4	30	7	1	5	6	12	114	84
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	65	14	1	63	14	0	36	4	0	9	3	0	173	35	1
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	24	50	6	22	51	4	21	18	1	5	7	0	72	126	11
12. Teach students to be precise in observation and expression.	70	9	1	70	7	0	38	3	0	12	0	0	190	19	1
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	50	30	0	52	22	1	32	9	0	11	1	0	145	62	1
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	53	27	0	55	20	1	35	6	0	11	1	0	154	54	1
15. Formulate, as well as answer, questions.	47	30	3	45	27	4	26	14	1	9	3	0	127	74	8

TABLE 26. (Continued)

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
16. Develop intellectual honesty rather than foster the search for the "right" answer.	63	16	1	67	8	1	37	3	1	11	1	0	178	28	3
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	37	37	5	43	32	1	27	13	1	9	3	0	116	85	7
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	36	41	3	42	32	3	30	9	1	9	3	0	117	85	7
19. Provide the student direct experiences related to concepts expounded in the classroom.	42	35	3	44	28	3	25	15	1	8	4	0	119	82	7
20. Demonstrate the extension of human sensory perception by appropriate instruments.	18	40	21	11	46	18	17	22	1	6	4	2	52	112	43
21. Develop selected manipulatory skills involved in laboratory techniques.	32	43	5	34	40	3	27	14	0	5	6	1	98	103	9

TABLE 26. (Continued)

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	33	39	7	34	41	1	25	15	1	8	4	0	100	99	9
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	30	40	9	29	43	4	21	19	1	6	6	0	86	108	14
24. Other															
a. Destroy the idea that chemistry is alien or magic.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
b. To read for content and understand it.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0

[a]A - very important

[b]S - some importance

[c]D - not at all important

possible list of objectives, an attempt was made to include both lecture and laboratory objectives and aims which have been recently discussed (within the past five years) in articles describing new first-year college chemistry innovations in individual institutions of higher education.

Two replies were not in proper form for tabulation and although additional comments were invited only two professors contributed additions. In one institution the questionnaire was answered by a committee of professors within the chemistry department; six institutions indicated two members, in consultation; completed the questionnaire while in others the professors as individuals filled in the answers.

Interpreting the data presented in Part II of the questionnaire proved to be rather difficult. The percentage approval which constitutes sufficient approval to justify the acceptance of a given aim as a general objective is very difficult. As a basis for discussion, when seventy-five percent of the replies are scored "very important," the objective is taken as generally accepted; and, when sixty-seven per cent score "very important," there is a sufficient majority to say that the objective is accepted by most professors. A percentage of fifty-five to sixty indicates only possible acceptance; conversely, a return of less than thirty-three percent response to "very important" indicates a rejection of the objective.

The preponderance of reaction from the professors as shown by an examination of data in Table 27 reveals that the "most important" selections from the list of 25 objectives and aims of general college chemistry (23 preselected and two additions), <u>which may be considered as generally accepted</u> (response to "very important" is 75 per cent or larger) to

TABLE 27. PERCENT OF INSTITUTIONS SCORING OBJECTIVES AS "VERY IMPORTANT"

Objective Number (See Table 26)	Percent of Institutions Responding				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	All Inst.
(1)	51	45	66	75	53
(2)	94	94	93	100	94
(3)	90	95	98	100	94
(4)	89	92	93	67	90
(5)	31	30	44	25	33
(6)	32	31	39	25	34
(7)	21	26	51	33	30
(8)	56	44	53	67	53
(9)	4	5	10	8	6
(10)	81	82	88	75	83
(11)	30	29	51	42	34
(12)	88	91	93	100	90
(13)	62	68	78	92	73
(14)	66	72	85	92	74
(15)	59	59	64	75	61
(16)	79	87	90	92	85
(17)	46	56	66	75	56
(18)	45	55	73	75	56
(19)	53	57	61	67	57
(20)	23	14	41	50	25
(21)	40	44	66	42	47
(22)	41	44	61	67	48
(23)	38	38	51	50	41

be: (1) develop the ability to do critical thinking (Table 26, Objective "3"), (2) make the students familiar with the facts, principles, and concepts of chemistry (Table 26, Objective "4"), (3) help the student to understand the nature of matter and its transformations (Table 26, Objective "2"), (4) develop the ability to handle quantitative problems (Table 26, Objective "10"), (5) develop intellectual honesty rather than foster the search for the "right" answer (Table 26, Objective "16"), and (6) teach students to be precise in observation and expression (Table 26,

TABLE 28. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY UNIVERSITIES

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
1. Show the relationship of chemistry to other sciences.	2	1	3	2	3	11
2. Help the student to understand the nature of matter and its transformations.	18	8	7	2	5	40
3. Develop the ability to do critical thinking.	22	18	9	8	2	59
4. Make students familiar with the facts, principles, and concepts of chemistry.	13	10	6	7	2	38
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	1	0	4	3	2	10
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	1	0	3	2	1	7
7. Give students an idea of the importance and significance of chemistry in our national life.	0	1	1	2	2	6
8. Development of specific interests, habits, and abilities which should be contributed to by <u>all courses</u> in science.	1	5	2	2	4	14
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	0	0	0	0	0	0
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	11	8	9	9	4	41
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	0	0	1	0	1	2

TABLE 28. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
12. Teach students to be precise in observation and expression.	1	5	4	13	9	32
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	2	1	3	3	5	14
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	0	1	1	1	2	5
15. Formulate, as well as answer, questions.	2	4	3	2	3	14
16. Develop intellectual honesty rather than foster the search for the "right" answer.	6	3	9	3	6	27
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	0	0	1	2	1	4
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	0	0	1	6	4	11
19. Provide the student direct experiences related to concepts expounded in the classroom.	0	2	2	0	2	6
20. Demonstrate the extension of human sensory perception by appropriate instruments.	0	0	0	0	0	0
21. Develop selected manipulatory skills involved in laboratory techniques.	0	1	1	2	7	11

TABLE 28. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	0	3	0	2	2	7
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	0	0	0	0	3	3
24. Other a. Destroy the idea that chemistry is alien or magic. b. To read for content and understand it.	0	0	0	0	0	0

TABLE 29. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY LIBERAL ARTS COLLEGES

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
1. Show the relationship of chemistry to other sciences.	2	0	0	2	3	7
2. Help the student to understand the nature of matter and its transformations.	19	9	7	3	4	42
3. Develop the ability to do critical thinking.	20	18	9	2	2	51
4. Make students familiar with the facts, principles, and concepts of chemistry.	17	13	13	7	1	51
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	0	0	1	1	0	2
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	0	4	1	2	2	9
7. Give students an idea of the importance and significance of chemistry in our national life.	0	0	1	4	1	6
8. Development of specific interests, habits, and abilities which should be contributed to by all courses in science.	2	1	2	6	2	13
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	0	0	0	0	0	0
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	1	4	8	10	5	28
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	0	1	0	1	0	2

TABLE 29. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
12. Teach students to be precise in observation and expression.	1	5	7	7	10	30
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	1	2	4	6	5	18
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	0		1	1	5	7
15. Formulate, as well as answer, questions.	0	4	1	5	0	10
16. Develop intellectual honesty rather than foster the search for the "right" answer.	6	5	11	6	7	35
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	0	0	0	3	3	6
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	0	0	2	0	4	6
19. Provide the student direct experiences related to concepts expounded in the classroom.	0	2	0	1	6	9
20. Demonstrate the extension of human sensory perception by appropriate instruments.	0	0	0	0	0	0
21. Develop selected manipulatory skills involved in laboratory techniques.	0	0	1	2	5	8

TABLE 29. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	1	0	2	1	3	7
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	0	1	0	0	1	2
24. Other a. Destroy the idea that chemistry is alien or magic. b. To read for content and understand it.	0	0	0	0	0	0

TABLE 30. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY JUNIOR COLLEGES

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
1. Show the relationship of chemistry to other sciences.	2	2	2	1	3	10
2. Help the student to understand the nature of matter and its transformations.	12	2	2	3	0	19
3. Develop the ability to do critical thinking.	7	10	2	1	1	21
4. Make students familiar with the facts, principles, and concepts of chemistry.	7	9	5	1	1	23
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	1	0	1	0	1	3
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	0	0	3	0	3	6
7. Give students an idea of the importance and significance of chemistry in our national life.	1	0	0	1	0	2
8. Development of specific interests, habits, and abilities which should be contributed to by <u>all courses</u> in science.	1	1	0	1	1	4
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	0	0	0	0	0	0
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	11	5	3	3	2	24
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	1	0	1	1	1	4

TABLE 30. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
12. Teach students to be precise in observation and expression.	2	1	3	4	4	14
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	1	0	5	5	0	11
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	1	1	0	0	0	2
15. Formulate, as well as answer, questions.	2	1	1	2	2	8
16. Develop intellectual honesty rather than foster the search for the "right" answer.	4	1	3	5	4	17
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	1	0	0	2	1	[illegible]
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	0	0	0	0	1	1
19. Provide the student direct experiences related to concepts expounded in the classroom.	0	0	2	2	2	6
20. Demonstrate the extension of human sensory perception by appropriate instruments.	0	0	C	0	1	1
21. Develop selected manipulatory skills involved in laboratory techniques.	0	0	0	1	2	3

TABLE 30. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	1	1	0	0	0	2
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	0	0	0	0	1	1
24. Other a. Destroy the idea that chemistry is alien or magic. b. To read for content and understand it.	0	0	0	0	0	0

TABLE 31. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY SPECIALIZED INSTITUTIONS

Statement	Frequency of Choice 1	2	3	4	5	Total No. of Respondents
1. Show the relationship of chemistry to other sciences.	2	0	0	1	0	3
2. Help the student to understand the nature of matter and its transformations.	1	0	4	1	0	6
3. Develop the ability to do critical thinking.	8	0	0	1	0	9
4. Make students familiar with the facts, principles, and concepts of chemistry.	1	2	0	0	2	5
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	0	0	0	0	0	0
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	0	0	0	0	0	0
7. Give students an idea of the importance and significance of chemistry in our national life.	0	0	0	0	0	0
8. Development of specific interests, habits, and abilities which should be contributed to by all courses in science.	0	1	0	0	1	2
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	0	0	0	0	0	0
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	0	1	0	1	0	2
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	0	0	2	0	0	2

TABLE 31. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
12. Teach students to be precise in observation and expression.	0	3	1	2	0	6
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	0	0	0	1	1	2
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	0	0	0	0	2	2
15. Formulate, as well as answer, questions.	0	0	1	0	0	1
16. Develop intellectual honesty rather than foster the search for the "right" answer.	0	2	2	1	0	5
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	0	1	0	1	0	2
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	0	0	0	0	2	2
19. Provide the student direct experiences related to concepts expounded in the classroom.	0	0	0	0	1	1
20. Demonstrate the extension of human sensory perception by appropriate instruments.	0	0	0	1	1	2
21. Develop selected manipulatory skills involved in laboratory techniques.	0	0	0	0	0	0

TABLE 31. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	2	4	2	3	5	16
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	0	1	0	0	5	6
24. Other a. Destroy the idea that chemistry is alien or magic. b. To read for content and understand it.	0	0	0	0	0	0

Objective "12").

From the literature survey of objectives (See Periodical Section of Bibliography), the investigator surmises that there are almost as many sets of objectives as there are chemists interested in first-year college chemistry. In this survey, however, agreement was found on several objectives of first-year college chemistry that may be considered as generally acceptable. When the respondents were asked to select and rank from the choice of objectives listed in Table 26 what they felt to be the five most important course objectives of general chemistry in the descending order of most important to least important (these data are presented in Tables 28, 29, 30, 31, and 32), the resulting data reveal that chemistry professors are concerned about course objectives and agree on some course objectives and aims. Selected from the objectives listed in Table 27, the university professors' choice and rank of five objectives that they considered as general objectives of freshman chemistry (in the order of most important to least important) are the objectives listed in Table 28 numbered "3," "10," "2," "4," and "12". The five choices of the liberal arts professors are "3," "4," "2," "16," and "12" (Table 29); the junior college professors five selections are objectives "10," "4," "3," "2," and "16" (Table 30); and the specialized institution professors' five choices are "3," "2," "12," "4," and "16" (Table 31); and, in summation, all college professors affirm in Table 32 the five most important general objectives of introductory college chemistry to be: (1) develop the ability to do critical thinking (Objective "3"), (2) make the students familiar with the facts, principles and concepts of chemistry (Objective "4"), (3) help the student to understand the

TABLE 32. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY ALL RESPONDENTS

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
1. Show the relationship of chemistry to other sciences.	8	3	5	6	9	31
2. Help the student to understand the nature of matter and its transformations.	50	19	20	9	9	107
3. Develop the ability to do critical thinking.	57	46	20	12	5	140
4. Make students familiar with the facts, principles, and concepts of chemistry.	38	34	24	15	6	117
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	2	0	6	4	3	15
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	1	4	7	4	6	22
7. Give students an idea of the importance and significance of chemistry in our national life.	1	1	2	7	3	14
8. Development of specific interests, habits, and abilities which should be contributed to by all courses in science.	4	8	4	9	8	33
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	0	0	0	0	0	0
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	23	18	20	23	11	95
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	1	1	4	2	2	10

TABLE 32. (Continued)

Statement	Frequency of Choice					Total No. of Respondents
	1	2	3	4	5	
12. Teach students to be precise in observation and expression.	4	14	15	26	23	82
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	4	3	12	15	11	45
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	1	2	2	2	9	16
15. Formulate, as well as answer, questions.	4	9	6	9	5	33
16. Develop intellectual honesty rather than foster the search for the "right" answer.	16	11	25	15	17	84
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	1	1	1	8	5	16
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	0	0	3	6	11	20
19. Provide the student direct experiences related to concepts expounded in the classroom.	0	4	4	3	11	22
20. Demonstrate the extension of human sensory perception by appropriate instruments.	0	0	0	1	2	3
21. Develop selected manipulatory skills involved in laboratory techniques.	0	1	2	5	14	22

nature of matter and its transformation (Objective "6"), (4) develop the ability to handle quantitative problems (Objective "10") and (5) develop intellectual honesty rather than foster the search for the "right" answer (Objective "16"). A comparison of the data in Tables 28, 29, 30, and 31 show that college professors, regardless of the classification of institution, agree on the five general objectives of freshman chemistry but disagree in their order of preference.

The objectives in Table 32 accepted by most professors (response to "very important" in Table 27 is at least 67 per cent but less than 75 per cent) are: (1) involve students in a scientific inquiry which combines theory and experiments in the solution of a problem (Objective "3"), (2) provide practice and reliable reporting of data and training in how to differentiate between relevant and irrelevant data (Objective "14").

The objectives in Table 27 which the professors ranked as indicating possible acceptance (a percentage return of 55 to 60 per cent) are: (1) development of special interest, habits, and abilities which should be contributed to by all courses of science (Objective "8"), (2) formulate, as well as answer questions (Objective "15"), (3) train the students to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedures (Objective "17"), (4) train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome (Objective "18"), (5) provide the student direct experiences related to concepts expounded in the classroom (Objective "19"), (6) develop selected manipulatory skills involved in laboratory techniques (Objective "21"), (7) bring the student to the point where he can function in a scientific laboratory (Objective "22").

TABLE 26-A. T-TEST OF SIGNIFICANCE

Topic	J.C. vs. Spec.	L.A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J.C.	Univ. vs. L.A.	L.A. vs. J.C.
Degrees of Freedom	51	87	92	121	157	116
Objectives and Aims of Introductory Course (See Table 26)	t-test					
	(1)	(2)	(3)	(4)	(5)	(6)
1	0.577	1.571	1.252	1.247	0.722	1.822
2	0.943	0.848	0.430	0.671	0.854	0.082
3	0.531	0.796	0.730	0.858	0.456	0.698
4	2.359*	2.631*	2.099*	0.192	0.146	0.091
5	1.338	0.657	0.915	0.789	0.659	1.401
6	1.315	1.159	1.268	0.192	0.334	0.478
7	1.244	0.123	0.159	2.469*	0.088	2.479*
8	0.855	1.170	0.567	0.427	1.457	0.819
9	1.845	0.074	0.300	2.322*	0.483	2.980*
10	1.419	0.546	0.546	1.177	0.163	1.490
11	0.620	1.094	0.771	2.250*	0.369	2.787*
12	0.943	1.076	0.904	0.510	0.328	0.324
13	1.035	1.268	1.645	1.282	0.658	0.683
14	0.548	1.256	1.445	1.758	0.396	1.415
15.	0.801	1.021	0.893	0.211	0.275	0.444
16	0.306	0.279	0.774	0.831	1.106	0.065
17	0.668	1.060	1.419	1.408	1.101	0.591
18	0.035	1.382	1.611	2.689*	0.582	2.273*
19	0.454	0.437	0.770	0.534	0.612	0.008
20	0.154	1.675	1.201	2.342*	0.633	3.151*
21	1.856	0.380	0.223	2.456*	0.253	2.435*
22	0.454	1.243	1.310	1.552	0.638	1.221
23	0.067	0.804	0.782	1.227	0.201	1.201
24	0.000	0.390	0.624	1.157	0.573	0.723

*Significant at the five per cent level of confidence.

The professors from all institutions surveyed, as shown in Table 32, rejected (response to objective is less than 33 per cent shown in Table 27) the following as general objectives of the introductory college

chemistry course: (1) acquaint students with new findings of chemistry and to point out their applications to everyday life (Objective "5"), (2) give students an idea of the importance and significance of chemistry in our national life (Objective "7"), and (3) expand the interest of individual students by encouraging hobbies (Objective "9").

The t-test scores of 2.359, 2.631 and 2.099 in Table 26-A, statement "4," columns "one," "two," and "three," show a significant difference at the five per cent level of confidence between the specialized institutions and the other colleges and universities with respect to objective "4" in Table 26: "make students familiar with the facts, principles, and concepts of chemistry--in favor of the specialized institutions." These statistics infer very little information, however, since all institutions accepted statement "4" in Table 26 as one of the five general objectives of first-year college chemistry.

Two additions were added to the list of possible objectives and aims. These are: (1) destroy the idea that chemistry is alien or magic, and (2) to read for content and understand it.

Course Evaluation

An excessive amount of staff time can be consumed when the evaluation procedures listed in Table 33 are used in evaluating the first-year college chemistry course. The selection of standards for evaluating a first-year college chemistry course are difficult whether it be short or long range.

Methods of Evaluating Success of Introductory Course

The tabulations concerning the ensuing methods of evaluating the

TABLE 33. METHODS OF EVALUATING THE SUCCESS OF THE INTRODUCTORY CHEMISTRY COURSE

Methods of Evaluation	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	S[a]	P[b]	T[c]	S	P	T	S	P	T	S	P	T	S	P	T
1. Special examination.	2	18	20	1	30	31	0	25	25	3	5	8	6	78	84
2. Subjective observations.	29	11	40	20	6	26	15	2	17	4	3	7	68	22	90
3. By using a student-completed questionnaire.	2	20	22	1	13	14	4	6	10	1	1	2	8	40	48
4. Discussion involving the entire chemistry faculty.	31	14	45	21	12	33	6	3	9	2	0	2	60	29	89
5. No evaluation.	0	0	7	0	0	8	0	0	2	0	0	2	0	0	19
6. Other															
a. Follow-up in subsequent courses.	0	0	0	0	0	0	2	2	4	0	0	0	2	2	4
b. Daily quiz.	0	0	0	0	1	1	1	0	1	0	0	0	1	1	2
c. ACS General Chemistry Examination.	0	4	4	0	7	7	0	3	3	0	0	0	0	14	14
d. Student or student committee evaluation.	1	4	5	0	1	1	0	0	0	0	0	0	1	5	6
e. Graduate Record Exam.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
f. Success of students (GRE) in graduate work.	3	0	3	2	1	3	0	0	0	0	0	0	5	1	6
g. Number and quality of students majoring in chemistry.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
h. Lab reports.	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
i. Test on qualitative unknowns.	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
j. Homework evaluated.	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
k. Subjective observations and student questionnaires.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
l. Departmental exams are given and periodically questionnaires are given to students.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
m. Discussion among faculty teaching the course.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1

TABLE 33. (Continued)

Methods of Evaluation	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	S	P	T	S	P	T	S	P	T	S	P	T	S	P	T
6. Other (continued)															
n. Course is evaluated very critically by the undergraduates in their annual independent publication, "Confidential Guide to Courses Regularly Open to Freshmen".	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
o. Combination or 2, 3, and 4.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
p. First 4 choices and performance in advanced courses.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
q. Informal discussions with students.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1

[a] S - spasmodic

[b] P - periodic

[c] T - Total

introductory college chemistry course from a preselected list including a space for additional methods under the choice "other" are listed in Table 33. The more popular methods used to evaluate the success of the first-year college chemistry course as shown in Table 33 are subjective observations (Method "2"); special examinations (Method "1"), and discussion involving the entire chemistry faculty (Method "4"). The evaluation methods, in general, were indicated to be spasmodic rather than periodic. The use of student completed questionnaires were indicated by 48 of the respondents (Method "3").

The additional comments of individual professors revealed helpful ideas related to successful methods of evaluating a course. These range from yearly evaluations to the follow-up and success of students in subsequent courses including graduate work. The data revealed (Method "5") that only 19 colleges and universities (a nine per cent response) indicated no course evaluation.

CHAPTER VI

SUPPLEMENTARY MATERIALS, EQUIPMENT, OUTSIDE MATERIALS, METHODOLOGY AND TEACHING TECHNIQUES

The portion of the survey covered in this chapter is a summarization of the supplementary materials and methodologies used by the chemistry professors in the sample in their introductory college chemistry courses. Materials and teaching methods are only incidentally mentioned in the literature and the list presented in Tables 34-37 is the result of literature findings.

Supplementary Materials, Methodology and Teaching Techniques

These two topics as shown in Tables 34 and 35 contain fifty-six items including a category of "other." The data in these two tables and the suggestions of the Advisory Council on College Chemistry[187] imply that a college professor should have the following supplementary teaching aids at his disposal: Television tapes (video tapes), a library of single concept film loops, a library of film loops on laboratory techniques, films, film loop projector, overhead projector and transparency sets, programmed materials, and computer assisted instruction (CAI).[188] AC_3 also specifies that effort be made to stimulate a series of outlines, paperbacks, and suggestions for teaching chemistry at the first year college level. The AC_3 publications and the survey findings in Tables 34 and 35 also show atomic and molecular models, journal articles, and

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[187] Haenisch, "Modern Teaching Aids for College Chemistry," pp. 1-2.

[188] Ibid., p. 21.

TABLE 34. NUMBER AND PERCENT OF INSTITUTIONS CHECKING SUPPLEMENTARY MATERIALS USED FOR INTRODUCTORY COLLEGE CHEMISTRY COURSES IN-CLASS BY INSTRUCTION AND OUTISDE-THE-CLASSROOM BY STUDENTS

Topic	Number of Institutions Responding											
	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Institutions			
	C[a]	O[b]	C	O	C	O	C	O	C	%	O	%
1. Faculty prepared study guides	8	22	19	26	12	15	3	5	42	20	68	32
2. Student personal data inventories	10	2	11	0	10	0	2	0	33	16	2	1
3. File of previously given tests	8	28	14	19	15	4	2	0	39	18	51	24
4. Bibliography of reading materials	1	20	3	30	5	15	1	1	10	5	66	31
5. Articles	11	18	15	21	16	21	2	1	44	21	61	29
6. Books	12	31	10	42	17	31	2	4	41	19	106	50
7. Film loops	7	4	12	4	17	7	1	0	37	17	15	7
8. Programmed materials	3	27	8	27	4	18	1	1	16	8	73	34
9. Other	3	3	1	2	1	0	0	0	5	2	5	2
(a) Study guide prepared by publisher	1	1	0	0	0	0	0	0	1	0	1	0
(b) Charts	1	1	0	0	0	0	0	0	1	0	1	0
(c) Workbook	1	1	0	0	0	0	0	0	1	0	1	0
(d) Single concept films	0	0	0	0	1	0	0	0	1	0	0	0
(e) Chemistry library	0	0	0	1	0	0	0	0	0	0	1	0
(f) Tape recordings	0	0	1	1	0	0	0	0	1	0	1	0
10. Atomic and molecular models	65	15	67	19	36	13	10	4	178	84	51	24
11. Film strips	14	0	26	1	22	1	5	0	67	32	2	1
12. Overhead projector	44	1	47	0	29	1	6	0	126	59	2	1
13. Opaque projector	13	1	14	0	10	1	3	0	40	19	2	1

TABLE 34. (Continued)

Topic	Number of Institutions Responding											
	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Institutions			
	C	O	C	O	C	O	C	O	C	%	O	%
14. 8 mm or 16 mm projector	30	1	33	1	23	1	4	0	90	42	3	1
15. Closed circuit TV	1	0	2	0	1	0	1	1	5	2	1	0
16. Other												
(a) Transparencies, slides	4	0	0	0	0	0	0	0	4	2	0	0
(b) 2" x 2" slide projector	1	0	0	0	0	0	0	0	1	0	0	0
(c) Demonstration spectroscope	1	0	0	0	0	0	0	0	1	0	0	0
(d) Demonstration magnetic susceptibility apparatus	1	0	0	0	0	0	0	0	1	0	0	0
17. Paperback books	15	61	15	59	10	22	4	10	44	21	152	72
18. Videotape	2	2	1	1	3	1	1	0	7	3	4	2
19. Computer assisted instruction	3	5	1	3	0	0	0	0	4	2	8	3
20. Supplementary paperback materials bought by students as part of supplies	0	0	1	1	0	0	0	0	1	0	1	0
21. Special lab and problem sets	1	1	0	0	0	0	0	0	1	0	1	0
22. Colored chalk	1	0	0	0	0	0	0	0	1	0	0	0

[a] C - Classroom

[b] O - Outside the classroom

supplementary books are worthwhile teaching aids and supplements.

The course outlines and syllabi which were either attached to or enclosed with the returned completed questionnaires also show recitation sessions, problem solving session, and student presentation of problems and solutions to be valuable aids to the learning of first-year college chemistry. Self-instruction, on the part of the student, can lend valuable aid and this assistance can come from programmed instruction, video tapes, film loops, and computer assisted instruction. Programmed lessons and other homework assignments were suggested by six professors in their additional comments as ways to handle some of the topics which students may not have mastered. Class time would then be free for topics that are new to all students.

A Summary of the Use of Supplementary Materials and Methodology and Teaching Techniques by Institutions

A summary of supplementary materials, methodology, and teaching techniques used by professors of introductory college chemistry participating in this survey is presented in Tables 34 and 35. Faculty prepared study guides are shown (Table 34, "All Institutions" column, item "one") to have a 20 per cent in-class use and a 30 per cent out-of-class use. The in-class and outside-the-class use of study guides at universities is 9.8 and 26.8 per cent respectively; in liberal arts colleges the per cent usage is 24.7 and 33.8; in junior colleges the per cent usage is 29.3 and 36.6; and in specialized institutions the per cent usage is 25.0 and 41.6—one respondent indicated the use of a commercial study guide. Does the discipline of chemistry require a special method of study? If so, why is the study guide being neglected by the majority of chemistry professors? The use of a-file-of-previously-

TABLE 35. METHODOLOGY AND TEACHING TECHNIQUES USED IN INTRODUCTORY COLLEGE CHEMISTRY

Methods and Techniques Used	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Demonstrations.	64	78	58	75	35	85	10	83	167	78
2. Panel Discussions.	3	3	2	2	1	2	0	0	6	2
3. Team teaching and/or committee teaching.	15	18	9	11	3	7	3	23	30	14
4. Programmed instruction.	18	21	23	29	9	21	1	8	51	24
5. Review sessions and/or tutorial sessions.	66	80	65	84	31	75	9	75	171	80
6. Conference quizzes.	23	28	13	16	7	17	0	0	43	20
7. Series of quizzes, tests.	57	69	65	84	37	90	10	83	168	79
8. Student conferences with faculty members.	44	53	53	68	31	75	9	75	137	64
9. Regular problem assignments.	67	81	67	85	40	97	10	83	183	86
10. Urge use of library for other than textbook reading.	36	43	46	59	29	70	8	66	119	56
11. Require term papers on topics not adequately covered in textbooks or secondary resources.	4	4	7	9	6	14	1	8	18	8
12. Special topics and reports.	6	7	11	14	9	21	1	8	27	12
13. Student presentation of problems and solutions.	10	12	18	23	9	21	3	25	40	18
14. Assign research journal articles for reading.	5	6	8	10	4	9	0	0	17	8
15. Presenting the limited but useful aspects of "black box" instruments.	15	18	5	6	3	7	2	16	25	11
16. Let student plan, execute, and interpret experiments.	9	10	11	14	6	14	3	25	29	13

TABLE 35. (Continued)

Methods and Techniques Used	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
17. Using "open-ended" experiments.	16	17	20	26	9	21	4	33	49	23
18. Devise experiments so that original sources must be consulted.	7	8	5	6	7	17	1	8	20	9
19. Using laboratory experiments which are not dependent on materials discussed in the classroom.	32	39	31	40	23	56	7	58	93	43
20. Using simple "mock-up" rather than complex apparatus to concentrate the student's attention on ideas rather than manipulation.	12	14	16	20	11	26	1	8	40	18
21. Other										
(a) Study topic in form of a symposium.	0	0	1	1	0	0	0	0	1	1
(b) Formal lectures and scheduled exams--3 exams per semester.	1	1	1	1	0	0	0	0	2	1
(c) Lots of give and take in class rather than formal, uninterrupted lecture.	0	0	1	1	0	0	0	0	1	1
(d) Use "teacher planned experiments" that students must perform and interpret accurately.	0	0	1	1	0	0	0	0	1	1
(e) Lectures modified by frequent oral quizzing and discussion.	0	0	1	1	0	0	0	0	1	1
(f) Laboratory experiment conducted in class.	1	1	0	0	0	0	0	0	1	1

given examinations is indicated by an 18 per cent in-class use and a 24 per cent outside-the-classroom use (the investigator has found that a file of old exams make good study guides and acquaint students with the type of test and the nature of questions to be expected on an exam). What is the rationalization behind this low per cent use of previously given examinations? Are old tests taboo or do professors fail to realize an educational value in making old examinations available?

The data in Table 34 (Items "7," "9-d," "9-f," "10," "11," "12," "13," "14," "15," "18," and "19") and Table 35 (Item "15") indicate that college professors who are teaching first-year college chemistry are not utilizing the modern teaching aids as suggested by the Advisory Council on College Chemistry.[189] Professors, however, are making full use of atomic and molecular models as evidenced by an 84 per cent in-class use and a 24 per cent outside-the-classroom use (Table 34, topic "10," "All Institutions" column). Professors are using the 8 mm and 16 mm projector, and the overhead projector as evidenced by a 42 per cent and a 59 per cent in-class use, respectively (Item "14," Table 34). The 17 per cent use of the film loops indicates that the 16 mm projector is, at present, the more important; although single concept films are now readily available only one respondent indicated use. A three per cent use of computer assisted instruction largely as an outside-the-classroom aid by universities, liberal arts colleges and specialized institutions was encouraging since computer assisted instruction has been approved and encouraged by the Advisory Council on College Chemistry. The professor's most popular teaching technique, other than lecture, is <u>demonstration</u> as evidenced

[189] Ibid.

by the data in Table 35 ("All Institutions" column, item "one"), by a 78 per cent use.

Several items in Tables 34 and 35, pertaining to self-instruction for students, were checked with a low per cent usage. These self-instruction materials listed in Table 34 are film loops (topic "7"), tape recording (topic "9"), video tape (topic "18") and computer assisted instruction (topic "19"); in Table 35 are student presentations of problems and solutions (method "13"), panel discussions (method "2"), special topics and reports (method "13"), research journal articles for reading (method "14"), programmed materials (method "4"). Assuming paperback books were used for this purpose, the out-of-class use, as shown in Table 34 (topic "17"), was 72 per cent and is encouraging since the Advisory Council on College Chemistry has suggested the use of paperbacks. One professor remarked that students were required to purchase supplementary paperbacks as part of their supplies. These previously mentioned self-instruction materials are shown in Table 34 ("All Institutions" column) to have an in-class usage which range from zero to 21 per cent and an out-of-class range from zero to 34 per cent.

Respondents indicated (Table 34, "All Institutions" column, topic "6") a 50 per cent out-of-class use of books and a 56 per cent use of library (Table 35, "All Institutions" column, method "10") for other than textbook reading, yet only 31 per cent (according to the data in Table 34, "All Institutions" column, topic "4") have compiled a bibliography of reading materials. What kinds of experience are the institutions of higher education providing for students in first-year college chemistry to assure proficiency in the retrieval of chemical information in the library?

The teaching method, second to the lecture, is shown by the data in Table 35 ("All Institutions" column, method "9") to be the <u>regular assignment of problems</u> as shown by an 86 per cent usage either daily or weekly. Other teaching methods listed in Table 35, in descending order of preference, are series of quizzes and tests (method "7"), and demonstrations (method "1") showing percentage use of 79 and 78 respectively. The respondents indicated an 80 per cent use of review sessions and/or tutorial sessions (method "5"); this allocation or reservation of time by professors to provide assistance to students is commended. Student conferences (method "6") were used by 53 per cent of the universities, 68 per cent of the liberal arts colleges, 75 per cent of the junior colleges and 75 per cent of the specialized institutions with a 64 per cent use by all institutions surveyed.

Regular problem assignments were used by 86 per cent of the institutions (Table 35, method "9") replying while student involvement in the presentation of problems and their solutions was indicated by only an 18 per cent use (method "13"). This implies that one institution out of five who assign problems allow the student to express himself by presenting problems and their solutions to the class. Probably the low per cent usage (11 per cent response to method "15" Table 35) can be attributed to the fact that black boxes in the first course is necessary only for illustrating certain basic principles, motivating the student, and perhaps use in student research. Most of these things can be accomplished by alternate methods.

According to Young[190] and the findings of this survey,[191] the

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[190] See p. 22 of this survey.

[191] See Tables 28-31, pp. 156-167 of this survey.

primary objective of the laboratory is to develop critical thinking; the low per cent response to the use of open-ended experiments (Table 35, "All Institutions" column, method "17")[192] infers that the laboratory is probably not being used to achieve its objective. Laboratory experiments, however, are currently being used which are not dependent on materials discussed in class as evidenced by a 43 per cent positive response in Table 35 (method "19"). This implies that some laboratory experiments are being used to illustrate and reinforce the lecture; a practice that meets the approval of the Advisory Council on College Chemistry. Individual panel members of the Advisory Council on College Chemistry have suggested library study to be an integral part of laboratory work; the findings of the survey (Table 35, items "10" and "14") indicate a library use of 56 and 8 per cent, respectively.

Equipment and Outside Materials

The Advisory Council on College Chemistry suggest that every chemistry department should have as part of its laboratory and demonstration equipment, in addition to a lecture table, a digital voltmeter or equivalent, pH meters, several automatic (single pan) balances, and spectrophotometric apparatus.[193] The pH meter and spectrophotometer provide means by which quantitative information can be gained in areas such as kinetics, metal-ion determination, buffer systems and weak acid-base titrations. Direct reading balances are valuable time savers and a necessary part of statistical work in the study of laboratory accuracy

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[192] The open-ended experiment allows a student to perform an experiment at his own pace (within limits), and is encouraged to find answers at the time they arise during the course of the laboratory work.

[193] Haenisch, "Modern Teaching Aids in College Chemistry," p. 2.

and precision and can be of real teaching value by permitting a wider latitude of experiments.

The investigator's feeling is that colleges and universities need to show interest in students and give them more than a two by four educational experience—inside the two book covers and the four walls. Resource speakers, clubs and social activities, open-ended investigations, and industrial trips are some of the methods that can be used.

Use of Equipment by Institutions

The decision to use the nine pre-selected items of apparatus in Table 36 was dictated by the suggestions of the Advisory Council on College Chemistry through their various publications and the members of the questionnaire evaluation committee. The colleges and universities show a high percentage use of direct reading balances. The principal use of the balances is for student experiments but they are also used in demonstrations and study of design. Direct reading balances (Table 36, Equipment "one") are used in student experiments by 73 of 82 universities, 46 of 77 liberal arts colleges, 31 of 41 junior colleges, and 7 of 12 specialized institutions, a total 157 out of 212 institutions (a percent use of 74). All respondents indicated a use of pH meters in student experiments (Table 36, Equipment "5") and a 25 percent use in demonstrations. The use of a spectrophotometer (Equipment "4") was evidenced by 38 percent response. The professors indicated the use of 30 other additional items of equipment in addition to that apparatus ordinarily assigned to students in laboratories. The geiger counter or scintillator (Table 36, Equipment "8") received a usage of 25 and 22 per cent. The low per cent use of equipment other than the single pan

TABLE 36. EQUIPMENT USED IN INTRODUCTORY COLLEGE CHEMISTRY

Equipment Used	Number of Institutions Responding																		
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Institutions						
	D[a]	SE[b]	SD[c]	D	SE	SD	D	SE	SD	D	SE	SD	D	%	SE	%	SD	%
1. Direct reading balances	8	73	2	17	46	6	8	31	2	5	7	0	38	18	157	74	10	5
2. Gas chromatograph	5	3	0	11	4	0	7	10	5	1	1	0	24	11	18	8	5	2
3. Infra-red spectrophotometer	6	6	1	13	5	1	3	5	2	1	1	0	23	11	17	8	4	2
4. Bausch and Lomb Spectronic 20	5	34	0	5	23	3	6	20	3	1	4	1	17	8	81	38	7	3
5. pH Meter	13	53	0	21	32	3	14	27	2	4	5	1	52	25	117	55	6	3
6. Conductivity bridge	5	14	0	9	5	0	2	3	2	1	2	0	17	8	24	11	2	1
7. Polarimeter	3	4	0	8	4	0	4	2	2	0	1	0	15	7	11	8	2	1
8. Geiger counter or scintillator	20	19	0	29	19	2	12	12	3	2	2	0	63	30	52	25	5	2
9. Paperchromatography	6	15	0	7	19	0	3	11	3	2	2	0	18	8	47	22	3	1
10. Other																		
a. Thin layer chromatography	0	2	0	0	1	0	0	3	0	0	0	0	0	0	6	3	0	0
b. Double pan analytical balances	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
c. Column chromatography	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
d. Photometer-flame, electrolytic analysis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
e. Colorimeter	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
f. Nuclear magnetic resonance	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
g. Vacuum tube voltmeter	0	1	0	0	3	0	0	0	0	0	0	0	0	0	4	2	0	0
h. Vacuum line-potentiometer	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
i. Welch chem. anal. system	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
j. Buoy balance	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
k. Beckman DU electrophoresis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
l. Ion exchange	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
m. Electrodeposition	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
n. Centrifuge	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
o. Chain-o-matic balances	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
p. Refractometer	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
q. Spectro-electro titrator	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0

[a] D - Demonstration

[b] SE - Student Experiments

[c] SD - Study of Design

balance, the spectrophotometer, and the pH meter raises several questions as to the nature of first-year college chemistry experiments.

The data in Table 37 ("All Institutions" column, item "4") show that only 72 (34 per cent) of all institutions in the sample utilize outside speakers; this raises the question about the utilization of existing resources to full advantage (a 49 per cent use of chemistry club activities and parties indicate low professor interest in chemistry students at the introductory level). Do college chemistry professors need to show more personal interest in students? The data tabulations in Table 37 (item "5") show that 50 per cent of the universities and 42 per cent of the liberal arts colleges are inviting eligible students to engage in chemistry club activities and social parties. Would the junior college (seven per cent response) and specialized institutions (four per cent response) also benefit from one of the few methods designed to improve and strengthen professor interest in students and hopefully, the converse?

Comparison of Methodology and Teaching Techniques Between Institutions

A tabulation of t-scores to determine whether a real difference exists between the means of the responses indicating the methodologies and teaching techniques used by chemistry professors in two comparable classification groups is presented in Table 35-A. The t-test scores show that there are no significant differences with respect to the methodology and teaching technique practices of the specialized institutions and the liberal arts colleges, and the specialized institutions and the junior colleges at the five per cent level of confidence. In

TABLE 37. OUTSIDE MATERIALS USED IN INTRODUCTORY COLLEGE CHEMISTRY

Materials Used	Number of Institutions Responding					
	Universities	Liberal Arts	Junior Colleges	Specialized	All Institutions	Percent
1. Field trips	9	17	11	1	38	18
2. Exploration trips	3	13	2	0	18	8
3. Local industry	6	19	8	0	33	16
4. Resource speakers	20	36	13	3	72	34
5. Chemistry club and parties	50	42	7	4	103	49
6. Other						
a. ACS affiliate	0	3	1	2	5	2
b. Educational Activity Period for research and demonstration	0	1	0	0	1	0
c. Occasional speakers to science club	0	1	0	0	1	0

TABLE 35-A. T-TEST OF SIGNIFICANCE

Methodology and Teaching Technique (See Table 35)	Groups of Institutions Compared					
	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
	(1)	(2)	(3)	(4)	(5)	(6)
(1)	0.166	0.596	0.409	0.954	0.401	1.259
(2)	0.531	0.556	0.664	0.354	0.379	0.051
(3)	1.671	1.234	0.540	1.616	1.153	0.738
(4)	1.035	1.554	1.083	0.000	1.131	0.909
(5)	0.042	0.793	0.433	0.615	0.642	1.156
(6)	1.523	1.534	2.127*	1.325	1.675	0.026
(7)	0.640	0.018	0.934	2.585*	2.011*	1.037
(8)	0.042	0.423	1.378	2.369*	1.960	0.763*
(9)	1.844	0.212	0.065	2.055*	0.260	2.032*
(10)	0.260	0.447	1.462	2.858*	1.997	1.168
(11)	0.548	0.083	0.487	1.860	1.037	0.903
(12)	1.035	0.551	0.122	2.350*	1.412	1.043
(13)	0.213	0.120	1.180	1.399	1.846	0.173
(14)	1.104	1.159	0.908	0.201	0.368	0.107
(15)	0.942	1.194	0.134	1.616	2.250*	0.167
(16)	0.813	0.929	1.339	0.576	0.622	0.050
(17)	0.779	0.523	1.074	0.312	0.964	0.476
(18)	0.721	0.231	0.023	1.392	0.482	1.803
(19)	0.132	1.160	1.259	1.790	0.157	1.635
(20)	1.323	1.005	0.580	1.625	1.007	0.734
(21)	0.000	0.796	0.539	0.998	0.902	1.476

*Significant at the five percent level of confidence.

regard to the use of conference quizzes (statement "6," Table 35), the universities show a significant difference (t-score = 2.127) over the specialized institutions at the five per cent level of confidence. This would indicate that university professors make more use of conference quizzes than do specialized institutions. The t-test scores for statements "10," "7," "8," "9," and "12" in Table 35-A are 2.858, 2.585, 2.369, 2.055, and 2.350 respectively, and show a significant difference

at the five per cent level of confidence in favor of the junior colleges over universities with respect to the use of the library for other than textbook readings; series of quizzes and tests; student conferences with faculty members; regular problem assignments; and special topics and reports. These statistics indicate that junior college professors are offering more self-assistance to students than do university professors. The t-test score of 2.011 for statement "7" in Table 35 favors the liberal arts colleges versus the universities with regard to quizzes and tests at the five per cent level of confidence, while the converse is true with respect to the use of "black box" instruments (t-test score = 2.255 for statement "15" in column "5," Table 35). The t-test score for statement "nine," column "six," Table 35-A, shows a significant difference which favors the junior colleges over the liberal arts colleges at the five per cent level of confidence with respect to the practice of regular assignment of problems. The t-test score of 2.858 in Table 35-A, statement "10," column "four" infer a significant difference of the junior colleges over the universities at the five per cent level of confidence with regard to urging students to use the library. These data show that junior college professors assign more library readings to students than university professors. Do these statistics infer that junior college professors are placing more emphasis on the teaching of introductory college chemistry than the other institutions of higher education?

CHAPTER VII

PROFESSOR REACTIONS TO STATEMENTS RELATED TO COURSE CHANGES, STUDENT INTEREST AND IMPROVEMENT OF TEACHING

Robert I. Walter,[194] L. Carroll King,[195] and the Advisory Council on College Chemistry[196] have alluded to the changes in general chemistry as largely due to the following forces: (1) the surfeit of knowledge appearing in the chemical literature and the rapid development of chemistry and other sciences; (2) the recent improvement in high school training in mathematics and the sciences and the impact of the CBA, CHEM, and PSSC courses; (3) that more equipment and more modern equipment is available for instructional use in undergraduate laboratories; and, finally, (4) the graduate schools have come to expect a higher level of training during the undergraduate years. AC_3 believes that the strongest force behind the changes currently taking place in the United States is the desire to emphasize the nature of the knowledge obtaining enterprise of the chemist and to take the student to the edge of research. Walter extended the discussion on course revision by stating: "Most teachers respond to these forces by making an effort to bring their students into contact with the frontiers of chemistry, and they make an effort to create for their students a sense of participation in science."[197]

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[194]Walter, p. 524.

[195]King, p. 126.

[196]Haenisch, "The Content of Introductory College Chemistry," p. 20.

[197]Walter, p. 524.

TABLE 38. TEACHER REACTIONS TO REASONS FOR CHANGING THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Statements	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
1. The availability of more equipment and more modern equipment for laboratory and instructional use.	42	51	42	54	24	58	5	41	113	53
2. Impact of CBA, CHEMS, PSSC courses.	29	35	33	42	10	24	2	16	74	34
3. The number of chemistry majors is diminishing.	19	23	18	23	12	29	1	8	50	23
4. Theories of chemistry are constantly developing.	41	50	48	62	21	51	7	58	117	55
5. Advent of general chemistry textbooks with a change in emphasis.	31	37	41	53	21	51	5	41	98	46
6. Flood of new information appearing in the chemical literature.	21	25	20	25	13	31	2	16	56	26
7. Large number of students beginning the study of introductory college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and/or mathematics.	36	43	38	49	18	43	3	25	95	45
8. Other										
(a) Requirements of American Chemical Society.	1	1	0	0	0	0	0	0	1	0
(b) Science is ever changing. Why should instruction stand still?	1	1	0	0	0	0	0	0	1	0
(c) Revision livens.	1	1	0	0	0	0	0	0	1	0
(d) Present lab is deadening rather than stimulating.	1	1	0	0	0	0	0	0	1	0
(e) Change 5 years ago and need to attempt evaluation.	1	1	0	0	0	0	0	0	1	0
(f) Change often catalyzes interest.	1	1	0	0	0	0	0	0	1	0
(g) Demand of the "Establishment" for more theoretically oriented course.	1	1	0	0	0	0	0	0	1	0
(h) Students are beginning to ask, "Why?"	1	1	0	0	0	0	0	0	1	0
(i) Course becomes stagnant without change.	1	1	0	0	0	0	0	0	1	0
(j) Growing need to integrate and demonstrate unity in science.	0	0	1	1	0	0	0	0	1	0
(k) Student population is changing.	0	0	1	1	0	0	0	0	1	0
(l) More is required by students in higher level courses.	0	0	1	1	0	0	0	0	1	0

TABLE 38. (Continued)

Statements	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
8. Other (continued)										
(m) Student interest is low in the present course.	0	0	1	1	0	0	0	0	1	0
(n) Simple need of instructor to seek constant improvement.	0	0	1	1	0	0	0	0	1	0
(o) Keep up with modern educational trends.	0	0	0	0	1	2	0	0	1	0
(p) Lack of student oriented teaching/inability to communicate the meaning of science.	0	0	0	0	1	2	0	0	1	0
(q) Mainly to give more lab experience.	0	0	0	0	1	2	0	0	1	0
(r) Too much in general chemistry courses.	0	0	0	0	1	2	0	0	1	0
(s) More thoroughly used teaching time, less "scanning".	0	0	0	0	1	2	0	0	1	0

Teacher Reactions to Reasons for Changing the Introductory College Chemistry Course

The responses to the statements relating to reasons for course changes, as shown in Table 38, resulted in a tally of 26 various reasons for change. A possible acceptance of all professors was directed to curricula changes brought about by: (1) theories of chemistry are constantly changing ("All Institutions" column, item "4" in Table 38) and (2) more equipment and more modern equipment are available for laboratory and instructional use ("All Institutions" column, item "1" in Table 38) as shown by a 55 and 53 per cent response, respectively. Two other factors which are also responsible for some course changes are: (1) the advent of general chemistry textbooks with a change in emphasis (Statement "5" in Table 38) and (2) the large number of students beginning the study of first-year college chemistry who are better prepared in terms of high school chemistry and mathematics (Statement "7" in Table 38) as evidenced by a 46 and 45 per cent response. To note that the professors from all institutions (Table 38) rejected the evidence of change due to the impact of Chemical Bond Approach (CBA), Chemistry Education Materials Study (CHEMS), and Physical Science Study Committee (PSSC) courses (Statement "2"), the diminishing number of chemistry majors (Statement "3") and the flood of new information appearing in the literature (Statement "6") was interesting. These factors have been more frequently mentioned in the literature as chiefly responsible for changes in first-year college chemistry curricula. The general objective of introductory college chemistry accepted by professors participating in the survey is to develop the ability to do critical thinking. CBA, CHEM Study, and PSSC innovations are inquiry oriented; why is it that these

courses have made very little, if any, impact upon the first-year college course? The data in Table 10 (Chapter IV, p. 97) show that only 14 per cent of the introductory college chemistry students have prior experience in one or more of these secondary science innovations (The data in Tables 10 and 38 imply a negative response to the emphasis placed on these secondary innovations as curriculum change agents since the data in Table 10 ("All Institutions" column, item "3") show only one student out of seven in this survey have had experience in one or more of these secondary science innovations prior to enrollment in introductory college chemistry and only 34 per cent of the professors (Table 38, "All Institutions" column, item "2") agree that the new secondary innovations have had a pronounced effect upon freshman college chemistry). The three secondary innovations listed in Table 38 are having a more pronounced effect upon the liberal arts colleges than the other three college categories as evidenced by the data in Table 38 by a 42 per cent response to statement "2." Not one professor mentioned "recent improvement in the teaching of high-school chemistry" as a factor.

The t-test score of 1.985 in Table 38-A, statement "6," column "6," shows a significant difference of the liberal arts colleges over the junior colleges at the five per cent level of significance with respect to the impact of CBA, CHEMS, and PSSC courses on the general chemistry curriculum. This data implies that more liberal arts professors than junior college professors feel these innovations have made a pronounced effect upon the freshman chemistry curriculum; however, these data infer little since the majority of the respondents (Table 38, statement "2") reject a pronounced effect on college curricula due to secondary science innovations.

TABLE 38-A. T-TEST OF SIGNIFICANCE

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
Reasons for Course Change (See Table 38)	t-test (1)	(2)	(3)	(4)	(5)	(6)
(1)	1.005	0.816	0.606	1.658	0.415	1.401
(2)	0.543	1.721	1.273	1.221	0.959	1.985*
(3)	1.463	1.168	1.159	0.724	0.030	0.689
(4)	0.418	0.260	0.529	0.125	1.559	1.154
(5)	0.562	0.732	0.252	1.408	1.954	0.206
(6)	0.990	0.682	0.660	0.703	0.052	0.651
(7)	1.149	1.479	1.226	0.000	0.519	0.423
(8)	1.251	1.076	1.269	0.000	0.626	0.523

*Significant at the five percent level of confidence.

The implication from the data in Tables 10 (Chapter IV, p. 97) and 38 is that no one knows just what the nature of the general chemistry course is; and, as a group, professional chemistry educators cannot come to a common agreement as to what forces are really producing curricula changes. One professor had this to say regarding this part of the survey: "Why don't people go their way or try their own ideas rather than trying to go by a consensus? A consensus of fools is still a consensus. Teaching of any course, if done with viability, is in constant change. I have probably never taught the same course in the same way. Our day to day innovations in our teaching and research should serve to keep our course

modern." The low use of sophisticated equipment[198] raises a question as to the validity of change brought about by the accessibility of new and modern equipment. This is probably true of the upper level chemistry course, but the impact is probably not felt on the introductory level.

Teacher Reactions to Statements of Factors That Reduce Student Interest

The professors from all categories (Table 39) listed 30 factors in addition to the pre-selected list of 16 supplied by the investigator which they felt to be responsible for limiting student interest in chemistry. The experience with these data was enlightening since there was a multitude of reasons listed; however, one topic, and only one (topic "1," Table 39), received mutual agreement among all four college classifications--topics are unrelated to student interest. The professors from all categories rejected the following factors in Table 39 as being responsible for reducing student interest: (1) too much theory (item "2"), (2) too much memory work (item "7"), (3) subject too formally presented (item "8"), (4) too much telling--too much teacher domination; failure of teacher to clarify a general principle (item "18") (5) failure to use "practical tangibles" in place of "textbook tangibles" (item "14"), (6) too little faculty time (item "15") and (7) poor instruction by graduate students (item "16"). The implication is that college professors feel that students loose interest in chemistry because of a lack of interest in the subject matter topics being presented (item "1," Table 39).

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[198] The use of sophisticated equipment other than the single pan balance and the pH meter was shown by the data in "All Institutions" column in Table 36 to range from a low usage of 8 per cent to a high of 38 per cent.

TABLE 39. TEACHER REACTIONS TO FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Topics are unrelated to student interest.	44	53	41	53	15	36	8	66	108	50
2. Too much theory.	30	36	24	31	17	41	4	33	75	35
3. Not enough laboratory work.	4	4	10	12	10	24	2	16	26	12
4. Insufficient or inadequate laboratory equipment.	26	31	21	27	12	29	3	25	62	29
5. Lack of library facilities.	2	2	5	6	6	14	1	8	14	6
6. Not enough individual work.	30	36	22	28	14	34	1	8	67	31
7. Too much memory work.	25	30	29	37	15	36	5	41	74	34
8. Subject too formally presented.	23	28	19	24	12	29	5	41	59	27
9. Instructor teaching too many subjects or students.	16	19	26	33	10	24	4	33	56	26
10. Facts taught as ends (products) of science rather than a means (processes) of science.	19	23	17	22	9	21	3	25	48	22
11. Too much teacher dependence on textbook.	9	10	16	20	12	29	4	33	41	19
12. Too much telling - too much teacher domination.	23	28	25	32	18	43	3	25	68	32
13. Failure of instructor to clarify a general principle.	13	15	17	22	6	14	3	25	38	18
14. Failure to use "practical tangibles" in place of "textbook tangibles."	10	12	18	23	8	19	4	33	40	18
15. Too little faculty time - too involved in research or other activities.	13	15	10	12	9	21	4	33	36	16

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
16. Poor instruction by graduate assistants.	22	26	5	6	5	12	3	25	35	16
17. Other										
(a) Student interest in grades (e.g. to avoid draft); atmosphere emphasizing grades discourages serious study; interest in "passing" rather than in learning.	2	2	1	1	1	2	0	0	4	2
(b) An introductory chemistry course is hard work and difficult and many students are just not willing to put forth the effort.	5	6	1	1	0	0	0	0	6	3
(c) "Fear" of chemistry-preoccupied idea of students that chemistry is a very difficult course.	1	1	1	1	0	0	0	0	2	1
(d) The lack of training in scientific thinking in their previous education (from K thru 12).	1	1	0	0	0	0	0	0	1	0
(e) Many students are fulfilling a requirement, not taking chemistry by choice - students not committed to a vocation.	2	2	1	1	0	0	0	0	3	1
(f) Topics unrelated to the scientific world in which the student will operate.	1	1	0	0	0	0	0	0	1	0
(g) Some students are not interested in worthwhile endeavors.	1	1	0	0	0	0	0	0	1	0
(h) Insistence of parents on science career for junior.	1	1	0	0	0	0	0	0	1	0
(i) Poor high school preparation in science and especially mathematics.	1	1	2	2	1	2	0	0	4	2

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
17. Other (continued)										
(j) Not enough demonstration to make principles real rather than abstract.	1	1	0	0	0	0	0	0	1	0
(k) Labs have not been as intellectually stimulating as they could be.	1	1	0	0	0	0	0	0	1	0
(l) The difficulty of establishing a perspective of the subject to which the student can relate the subject matter being presented.	1	1	0	0	0	0	0	0	1	0
(m) Freshmen very poorly disciplined and do not keep up with curriculum.	1	1	0	0	0	0	0	0	1	0
(n) Too little feedback or exchange.	1	1	0	0	0	0	0	0	1	0
(o) None of the above apply. Students are busy with other courses.	1	1	0	0	0	0	0	0	1	0
(p) Too many topics in such a short time. Students are overwhelmed.	1	1	0	0	0	0	0	0	0	0
(q) Previous experience with science and the interest of the individual.	0	0	1	1	0	0	0	0	1	0
(r) Too much competition for students time and attention by other courses and campus activities - lack of willingness of students to work seriously.	0	0	4	5	2	5	0	0	6	3
(s) Too much laboratory work.	0	0	1	1	0	0	0	0	1	0
(t) Too much theory too early.	0	0	1	1	0	0	0	0	1	0

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
17. Other (continued)										
(u) I don't know - certainly varies with the student.	0	0	1	1	0	0	0	0	1	0
(v) Course takes too much application and ability for many.	0	0	1	1	0	0	0	0	1	0
(w) The concepts are frequently difficult for some students. If a student fails to learn something well at the beginning of the course, he will invariably have trouble later.	0	0	1	1	0	0	0	0	1	0
(x) Students want courses that do not necessitate study every day.	0	0	1	1	0	0	0	0	1	0
(y) Professor overworked.	0	0	0	0	1	2	0	0	1	0
(z) People interested in their check and not teaching.	0	0	0	0	1	2	0	0	1	0
(aa) Bad textbooks (books written for amusement of instructors and not for the instruction of students).	0	0	0	0	1	2	0	0	1	0
(bb) Use of the whole gamut of subject materials in a single "Introductory" course.	0	0	0	0	1	2	0	0	1	0
(cc) Prestige seeking by faculty.	0	0	0	0	1	2	0	0	1	0
(dd) You name it and someone will have it.	0	0	0	0	0	0	1	8	1	0

What factors are responsible for low student interest in a topic? Is the lack of interest due to the topic or to the professor's method of presentation? Professors made the above ratings, how would students rank these topics? The Advisory Council on College Chemistry is of the opinion that too little faculty time and poor instruction by graduate students are the principal factors that are likely to cause the quality of instruction in first-year college chemistry to suffer. Do chemistry professors still acquaint teaching with telling but do not recognize it or refuse to admit it? The Advisory Council on College Chemistry states that the instruction in introductory college chemistry suffers from large class size and from professor involvement in research.[199] The data in Table 38 show that the college professors in this survey rejected the first statement as evidenced by a 45 per cent acceptance of topic "7" in Table 38 and a 26 per cent approval of item "9" in Table 39 and the latter statement by a 16 per cent response to item "15" in Table 39.

An analysis of the above information leads the investigator to surmise that chemistry professors need to take a serious look at their pedagogical practices and develop some methods and techniques with the ensuing goal to increase student interest in lecture topics. An analysis of the factors which cause lack of interest is needed. The professors have indicated factors which may cause the lack of interest but cannot come to any agreement as to the most influential. Probably the two most honest appraisals were, "I don't know--certainly varies with the students," and "You name it and someone will have it."

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[199] "Big Classes Create Big Problems," Chemical and Engineering News, 41, October 28, 1963, pp. 48-50.

TABLE 40. NUMBER OF TEACHER REACTIONS TO DEVELOPMENT OF ITEMS TO IMPROVE THE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests.	15	31	27	19	32	18	12	19	10	5	4	2	51	86	57
B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as content and the ability to do critical thinking.	23	38	9	37	25	6	24	10	2	7	3	1	91	76	18
C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching.	25	32	16	32	32	6	24	11	1	6	4	0	87	79	23
D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching technique) and in the methods of educating college teachers of chemistry.	37	26	11	40	27	3	21	13	4	6	5	0	104	71	18

TABLE 40. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten.	43	20	7	42	22	5	25	10	1	7	2	2	117	54	15
F. Other	9	0	0	4	0	0	4	0	0	0	0	0	17	0	0

[a] A - very important

[b] S - some importance

[c] D - not at all important

Interpreting the data presented in Table 40 proved to be especially difficult. To assist in that interpretation the following procedure was designed to evaluate the teacher responses in Table 40 to statements related to suggestions for the improvement of the teaching of introductory college chemistry. Each topic in Table 40 is evaluated by assigning the following numerical values: Column one, three points; Column two, two points; and Column three, one point. The number of points for each topic is added to get an actual score. The percentile score is calculated by multiplying the number of respondents checking that topic by the number of points assigned to the column.

Example: Topic "one" is checked by 25 professors. Thus 25x3 = 75 = highest possible score.

Professor Responses to Statement of Suggestions for Improvement

There was sufficient data in Table 39 to indicate that professors believe the major reason for the lack of or loss of student interest in first-year college chemistry is <u>topics are unrelated to student interest</u>. The data in Table 40 (item "A" in "Total" column) show 51 (24 per cent) of these professors agree that test-like instruments (inventories and checklists) are needed to ascertain and challenge interests of students. The data in Table 41 (item "A") show 37, 41, 46, and 35 per cent of the professors surveyed in the various categories of institutions (an average of 40 per cent from total number of professors) indicated interest of "some importance" with respect to the developments of scales to determine and maintain student interest in introductory college chemistry topics ("Total" column, item "A"). One professor made a very worthwhile additional comment to the last statement. He wrote, "I consider development

TABLE 41. PERCENT OF TEACHER REACTIONS OF DEVELOPMENT OF ITEMS TO IMPROVE THE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests.	18	37	32	24	41	25	29	46	24	41	33	16	24	40	26
B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as content and the ability to do critical thinking.	28	46	10	48	32	7	58	24	4	58	25	8	42	35	8
C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching.	30	39	19	41	41	7	58	26	2	50	33	0	41	37	10
D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching technique) and in the methods of educating college teachers of chemistry.	45	31	13	51	35	3	51	31	9	50	41	0	49	33	8
E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the															

TABLE 41. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten.	52	24	8	54	28	6	60	24	2	58	16	16	55	25	7
F. Other															
1. Change high school chemistry courses so that they teach a few areas well, i.e., atomic structure, gas laws, acid-base theory, and leave all else to college courses.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
2. Hammond Curriculum.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
3. The ACS test could measure both the achievements of students and the teachers.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
4. Teacher dedication.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
5. Improvement of laboratory exercises to illustrate pertinent points.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
6. A revised standard for what are appropriate and attainable goals.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
7. A good 12 week qualitative analysis course ties chemistry together especially on requiring balanced equations for all reactions possible.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
8. Readable textbooks need to be written.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
9. Teach (a) the art of discriminatory thinking and (b) the necessary factual bases.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0

TABLE 41. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
F. Other (continued)															
10. A very strong involvement—and a not direct one—of senior faculty participation in all levels of courses.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
11. Stop teaching course as if for chemistry majors only.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12. Beware of eliminating descriptive material to the extent that the students don't understand the behavior of matter on an everyday basis.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
13. Training of teachers for 2 year colleges is of particular importance.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
14. Methods of teacher-student interaction. Rapid growth of our institutions and many others leave numerous students without personal relations with faculty.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15. Development of teaching procedures to meet the needs and interests.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

[a]A - very important

[b]S - some importance

[c]D - not at all important

of teaching procedures to meet needs and interest to be very important. The development of test-like instruments to do this I cannot conceive."

TABLE 42. ASSESSMENT OF TEACHER REACTIONS TO STATEMENTS RELATED TO THE IMPROVEMENT OF TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Topic from Table 40	Responses* A (1)	S (2)	D (3)	Number of Checks	Possible Score	Actual Score	Percent Value
A	51	86	57	194	582	382	66
B	91	76	18	185	555	443	80
C	87	79	23	181	543	422	78
D	104	71	18	193	579	472	82
E	117	54	15	186	558	474	85

*Column "5," Table 40.

The implication of a need for course improvement was generally accepted by all respondents in the survey as evidenced by the data in the "per cent value" column in Table 42 which shows an approval ranging from 66 to 85 per cent. The data in Table 42, including the additional information in Table 41, gave sufficient evidence to justify a revolution in attitudes and methods of teaching freshman chemistry (topic "D") and in the methods of educating college teachers of chemistry even to the point of retraining those people presently engaged in teaching first-year college chemistry (topic "C"). The implication of the need to teach chemistry as a process is very strong as indicated in Table 42 (topic "E") by an 85 per cent value. Noteworthy comments which suggested methods to help increase student interest were offered by two university professors. One professor suggested the need for methods to achieve teacher-student interaction and the other asked for the development of teaching

TABLE 42-A. T-TEST OF SIGNIFICANCE

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
Ideas for Improvement (See Tables 41 and 42)	t-test (1)	(2)	(3)	(4)	(5)	(6)
A	1.411	0.676	1.135	0.140	0.969	1.018
B	0.461	0.122	0.752	0.981	1.293	0.960
C	0.124	1.348	1.805	2.918*	1.402	1.976*
D	0.421	0.020	0.598	0.306	1.204	0.715
E	1.012	0.434	0.573	0.657	0.346	1.003

*Significant at the five percent level of confidence.

procedures to meet student needs and interests. One professor advocated the adoption of the Hammond Curriculum. Still another professor remarked, "The most difficult 'nut' to crack is the professor's notion that what he learned and taught for many years should still be the core of his teaching."

In general, all four classifications of colleges were in mutual agreement regarding the statements relating to course improvement. The t-test scores of 2.918 and 1.976 in Table 42-A, statement "C," columns "4" and "6," however, show a significant difference in favor of the junior colleges when compared with the universities and liberal arts colleges at the five per cent level of confidence with respect to the urgent need for retraining of the current professors of freshman chemistry. This means that a higher per cent of junior college professors

are in favor of the retraining of their colleagues than are university and liberal arts professors. In regard to other suggestions, the four classifications were in mutual agreement.

CHAPTER VIII

COURSE CONTENT TOPICS, RECITATION TOPICS AND LABORATORY EXPERIMENTS

The cooperating institutions were asked to supply the investigator with syllabi or course outlines for their introductory college chemistry courses. The responses for a description of lecture topics was less than eight per cent; 15 syllabi were received.

Each lecture topic on each syllabi (or course outline) was interpreted and identified with a specific topic or subtopic. These data are summarized in Table 43. As the classification of topics developed during the evaluation of the syllabi and course outlines, the investigator made the decision to divide the major subject matter topics into nine major areas, each of which is further subdivided as indicated in Table 43.

To assist in the interpretation of the data presented in Table 43, these comments are made: whenever a topic could be classified under more than one heading, it was classified under the most specific heading. Arbitrarily, each successive heading in Table 43 is presumed to be, by its relative position, more specific than the preceding heading. Thus, for example, a topic dealing with the Nucleus and Radioactivity was placed under, "Atomic Structure," rather than under, "Nuclear Chemistry," or "Nuclear Structure." Further, a topic dealing with Balancing Oxidation and Reduction Equations was classified under "Oxidation-Reduction Reaction" rather than the topic, "Stoichiometry."

Ambiquities in Table 43, where foreseen, were classified by notes.

TABLE 43. NUMBER OF MAJOR LECTURE TOPICS APPEARING ON 15 FIRST-YEAR COLLEGE CHEMISTRY COURSE SYLLABI

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
1. Atomic Structure	6	5	3	1	15	1-15	7.0
A. Atomic Nature of Matter	3	3	2	1	9	1-3	2.0
1. Atomic Theory to Dalton							
2. Dalton's Atomic Hypothesis							
B. Modern Views on Atomic Structure	4	2	2	1	9	2-15	7.0
1. History of the Quantum Concept[a]							
2. Schrodinger's Wave Equation							
3. Electron Cloud and Ionization[b]							
4. Quantum Mechanics and Picture of Atom							
5. Atomic Number and Isotopes							
C. Nuclear Structure and Radioactivity	1	2	3	0	6	1-9	5.0
1. Nuclear Structure and Properties							
2. Nuclear Models							
3. Nucleus and Radioactivity							
4. Nuclear Stability and Binding Energy							
5. Nuclear Reactions: fission and fusion							
6. Rate of Radioactive Decay							
7. Application of Radioisotopes in Chemistry							
8. Atomic Energy for Peace							
2. Chemical Bonding	6	5	3	1	15	1-15	8.5
A. Chemical Bonding and Molecular Structure	6	5	3	1	15	3-15	4.6
1. Fundamentals of Variation Theory							
2. Molecular Orbital Theory							
3. Valence Bond Theory							
4. Thermodynamic Aspects[c]							
5. Electronic Aspects[d]							
a. Ionic Bonding							
b. Covalent Bonding							
c. Metallic Bonding							
B. Bonding in Coordination Compounds	1	1	0	0	1	2	2.0
1. Valence Bond Theory							

TABLE 43. (Continued)

Topic	Number of Responses: Univ.	Lib. Arts	Jr. Coll.	Spec.	Total	Range of Lectures per Topic	Average Number of Lectures per Topic
2. Chemical Bonding (Continued)							
B. Bonding in Coordination Compounds							
2. Crystal Field Theory							
3. Ligand Field Theory							
C. The Nature of Compounds	0	1	0	0	1	1	1.0
1. Gay-Lussac's Law of Combining Volumes							
2. Cannizaro and Avogadro's Hypothesis							
D. Molecular Compounds	3	2	1	0	6	10	1.7
1. Formula Types[e]							
2. Ionic Compounds[f]							
3. States of Matter and Solutions	6	5	3	1	15	1-10	6.4
A. State of Matter	6	5	3	1	15	1-10	3.0
1. Gases[g]							
2. Solids[h]							
3. Liquids[i]							
B. Properties of Solutions	5	1	2	0	8	1-6	2.0
1. Solutions: activities and colligative properties							
2. Ideal Solutions[j]							
3. Non-ideal Solution: criteria and Causes							
4. Stability[k]							
4. Stoichiometry	6	5	3	1	15	1-9	2.0
A. Atomic Weights[l]							
B. Mole Concept							
C. Molecular Weight Calculations[m]							
D. Chemical Equations							
1. Significance							
2. Types: complete, ionic, essentially ionic							
E. Balancing Equations							
F. Yield Problems (gas yield at STP)							
G. Atomic Weight from Reaction							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
4. Stoichiometry (Continued)							
H. Chemical Factor							
I. Indirect Calculations							
J. Concentrations of Solutions							
1. Methods of Stating Concentration							
2. Preparation and dilution of solutions							
3. Reactions and Stoichiometry of Solutions							
5. Chemical Equilibrium	6	5	3	1	15	1-13	6.4
A. General Aspects	4	2	3	1	10	1-13	2.6
1. Reversibility, Spontaneous, independence of starting point							
2. Equilibrium Constant, Law of Mass Action, Conventions Employed							
3. External Conditions and Equilibria							
4. Corrections for Non-ideal Behavior							
5. Equilibrium State from Initial Conditions							
B. Ionic Equilibrium in Aqueous Solution	6	5	3	1	15	1-6	3.6
1. Sparingly Soluble Salts[n]							
2. Acids and Bases[o]							
3. Acid-Base Reaction							
4. Auto-dissociation of solvent: K_a, K_i, pH							
5. Hydrolysis							
6. Neutralization and Titration[p]							
7. Multistate Equilibria							
C. Oxidation-Reduction Reaction	2	2	3	1	8	1-6	3.6
1. Definition of Terms							
2. Relation to Cell Processes							
3. Balancing Oxidation-Reduction equations							
a. Half-cell Method							
b. Oxidation Number Method							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
5. Chemical Equilibrium (Continued)							
C. Oxidation-Reduction Reaction							
4. Electro-chemical Cells[q]							
5. Oxidation-Reduction Titrations							
6. Chemical Kinetics	6	5	3	1	15	1-9	3.8
A. Concentration and Rate (Rate Laws)							
B. Reaction Mechanisms							
C. Models for Reaction (Collision Models for Reaction)							
D. Reaction and Equilibrium							
E. Collision Theory							
F. Temperature Dependence on Reaction Rate							
G. Catalysis							
7. Chemical Reactivity	6	5	3	1	15	1-20	4.8
A. Chemical Reactions	4	2	3	1	10	1-2	1.5
B. Thermodynamics	6	3	2	1	15	1-20	4.9
1. Definitions Reviewed and Calculations of W and Q							
2. First Law (Energy Changes in simple processes, Thermochemistry[r]							
3. Second Law[s]							
4. Third Law: Entrophies							
5. Free Energy							
a. Delta G and Equilibrium Constant							
b. Electrochemistry (Delta G and Electrochemical Cells)							
c. Delta G and Temperature Dependence of equilibrium							
d. Gibbs-Helmholtz Equation							
e. Colligative Properties Revisited							
8. Descriptive Chemistry	4	2	3	1	10	1-2	1.5
A. Metallic Elements	4	1	3	1	9	3-8	5.0
1. Metallurgy							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
8. Descriptive Chemistry (Continued)							
A. Metallic Elements							
2. Active Metals of Main Group I, II, III							
3. Post-transistior Elements of Main Groups III, IV, V							
4. Transistion Elements (d-orbital, lanthanide, actinide)							
5. Cation Analysis							
B. Non-metallic Elements	6	5	3	1	15	1-11	3.3
1. Noble Gases							
2. Halogen Elements							
3. Sulfur and oxides							
4. Group V Non-metals							
5. Boron, Silicon, Germanium							
6. Hydrogen and Hydrides							
C. Hydrogen, Oxygen, and Water	2	0	2	0	4	1	1.0
D. Inorganic Chemistry	3	3	3	1	10	1-10	3.5
1. Periodic Relationships[t]							
2. Transistion Metal Complexes: Magnetic and Optical Properties							
3. Certain oxides and Hydroxides							
E. Organic Chemistry[u]	3	2	3	0	8	3-12	7.0
9. Other Topics							
A. Basic Information (Understanding the Language of Science)	3	2	3	0	8	1-5	3.0
1. Working Definitions[v]							
B. Nomenclature of Compounds	1	2	3	0	5	1-2	1.4
1. Rules for Assigning Oxidation Number							
2. Naming Binary Compounds							
3. Naming Compounds of High Order							
C. Biological Chemistry[w]	3	0	0	0	3	1-10	3.0
D. Colloidal Chemistry	0	2	0	0	2	3	3.0

TABLE 43. (Continued)

[a]Planck's hypothesis, specific heat of solids, photoelectric effect, Bohr theory, and new picture: de Broglie, Compton, Heisenberg.

[b]Auf-Bau principle, Pauli principle, sheilding, ionization potential, electron affinity, orbitals, electronegativity.

[c]Bond energies, bond length, bond angles.

[d]Ionic crystals, X-ray determination, some common structures, lattice stabilities energy, Born-Haber Cycle, valence stability, Pauling's rules and ratio.

[e]Empirical, molecular, and structural.

[f]Formulas, types of ions: simple, compound, complex.

[g]Ideal Gas Laws, simple kinetic theory, real gases.

[h]Forces in crystals, determination of structure, classification of structure.

[i]Forces in liquids, phase changes.

[j]Raoult's law, boiling point and freezing point of solutions, volatile solutes and distillation.

[k]Conditions influencing, La Chalalier's principle.

[l]Atomic symbols and significance, multiple properties, and equivalent proportions. Rule of greatest simplicity, Avogadro's hypothesis, DuLong and Petit, Modern Methods.

[m]Calculations: molecular weight, per cent composition, formula from per cent composition.

[n]Solubility product (K_{sp}), common-ion effect, selective precipitation.

[o]Arrhenius theory, Bronsted-Lowry theory, Lewis theory.

[p]Dilution effect, reaction effect, buffer effect.

[q]Current effects, voltage effects, Nernst equation.

[r]Energy changes in simple processes, internal energy (delta E), enthalapy or heat content (delta H).

TABLE 43. (Continued)

[s]Entropy, spontaneity, free energy, definition of entropy (delta S).

[t]Arrangement of periodic table: variation of properties, conductive properties, radius, acidity of binary acids, oxy-acids.

[u]Carbon and organic compounds: alakanes, functional groups, aromatic compounds, isomerism.

[v]Chemistry, matter-division and types of properties, systems (open, closed, isolated and conserved), energy, heat, basic concepts, measurements, and substances.

[w]Biopolymers, enzyme catalysis, antibiotics, chemistry and living.

Thus, for example, the note in Table 43 (Note "q") which refers to electro-chemical cells indicates that electrochemistry is so classified under "Oxidation-Reduction Reactions" while other chemical reactions are classified under the major topic "Chemical Reactivity," or its subtopic, "Thermodynamics." Hence, the study of atomic weight calculations would not be classified under "Atomic Structure," but under "Stoichiometry."

The college and classification type, in all 15 cases, were indicated by each respondent: six institutions were from the university category; five from the liberal arts; three from junior college, and one from specialized institutions. Hence with respect to the classification distribution of the 15 institutions of higher learning responding, the sample is weighted slightly in favor of universities (40 per cent). One-third of the replies were from liberal arts colleges, one-fifth from junior colleges and one reply from a specialized institution.

The data presented in Table 43 were obtained from course outlines and syllabi; hence some topics were eclipsed and do not appear explicitly in the tabulations. The numbers in the table are the counted numbers of topics found for each major topic listed. Qualitatively, then they suggest relative emphases. Course outlines from two of the responding institutions emphasized one or more closely defined areas such as thermodynamics (12 and 20 lectures), Quantum Theory (15 lectures), or Chemical Bonding (15 lectures). The syllabi and course outlines differed so greatly that the investigator was unable to devise a satisfactory method to compare the sequence order in which the topics were presented; for example, Nuclear Chemistry is taught all across the spectrum of the academic year. A summary of the lecture topics tabulated from the 15 course

syllabi is presented in Table 43.

Many professors attached notes to the questionnaire explaining that they did not have time to prepare a syllabus or stated that the syllabus of the course was changing so rapidly that it would not be representative of the course currently offered.

In addition to the description of lecture topics, eight[200] of the 15 responding institutions included outline descriptions of their recitation sessions (problem sessions, problem discussions, pre-laboratory quizzes, homework, examinations, and reviews); only six[201] of these respondents discussed their laboratory activities. The data which describe the topics covered in these recitation sessions are presented in Table 44. These eight syllabi reveal that some colleges and universities are, in addition to lecture and laboratory, devoting from one to two hours per week to recitation sessions. Major topic Number "5" (Stoichiometry) in Table 43 and the Topic Titles listed in Table 44 suggest that college chemistry professors are placing an important emphasis upon stoichiometry, either in recitation sessions or lecture sections; the sample is weighted slightly in favor of recitation sessions since eight of the 15 responding institutions have regularly scheduled problem sessions. Two of these eight institutions scheduled two-hour periods for problem sessions and quizzes while the remaining six alloted a period of

[200] Of the eight responding institutions, two included the recitation sessions as an integral part of the lecture phase of the course; the remaining six included the recitation sessions as a part of the laboratory activity, either pre-laboratory or post-laboratory.

[201] One institution listed the Laboratory Manual Title but failed to list the experiments performed; another institution listed the page numbers to their own departmental laboratory manual but failed to send a description or titles of the experiments used.

one hour. The schedules for lectures and recitations was listed as follows: Three institutions used the two one-hour lecture and one one-hour recitation schedule; two institutions used a three one-hour lecture and one two-hour recitation schedule, while the remaining three institutions used the three one-hour lecture and the one one-hour recitation period schedule. The data collected from the 15 syllabi in Table 43 are insufficient to determine a trend since they represent less than a ten per cent response; however, the variation and differences in the previously discussed syllabi lead the investigator to suggest that another study is needed to determine the nature of and the extent of usage of recitation sessions. That 86 per cent of the responding institutions offer problem assignments (See Table 35, p. 181), without any further description or additional comments, reveal further support for the need to study recitation sessions on a nation-wide basis. How much time is devoted to problem sessions? The investigator suggests that the Advisory Council on College Chemistry, the American Chemical Society, or some other professional organization and/or committee request and examine problem session outlines and schedules from a large number of colleges and universities.

The listing of textbook titles, laboratory manual titles, and supplementary book titles was the exception rather than the rule. In addition to the 15 professors who sent course syllabi, only three other professors listed lecture textbook titles; a total of 18 textbooks and 14 different titles. Ten professors (six of these sent syllabi or outlines) listed the laboratory manual titles (three departments had written

TABLE 44. TOPICS COVERED IN A ONE OR TWO HOUR RECITATION SESSION

Topic	Number of Institutions Responding					Range of Sessions per Topic (8 Syllabi)	Total Hours on Topic (8 Inst.)	Average Number of Hours per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total			
1. Measurements: density and specific gravity.	0	3	2	0	5	1-2	5	1
2. Atomic weights, molecular weights and moles.	1	3	2	0	6	1-2	10	1.7
3. Composition Calculations, Calculations from Chemical Equations.	0	3	2	0	5	1	5	1
4. Temperature measurement and measurement of gases.	1	3	1	0	5	1-3	7	1.4
5. Molecular weights of gases.	1	3	1	0	5	1	5	1
6. Electrochemistry.	1	3	1	0	5	1	5	1
7. Equivalent weight, valence, oxidation state.	0	2	2	0	4	1-2	7	1.7
8. Expressing concentrations of solutions and properties of solutions.	0	2	2	0	4	1-2	7	1.7
9. Reactions involving normal solutions.	0	2	2	0	4	1	4	1
10. Chemical equilibrium.	3	3	2	0	8	1-3	12	1.5
11. Ionic equilibrium.	1	3	2	0	6	1	6	1
12. Solubility Product and precipitation.	1	3	2	0	6	1-2	7	1.2
13. Review of principles, including topics suggested by students.	0	0	1	0	1	1	1	1
14. Basic concepts[a] of mathematics in chemistry.	0	3	2	0	5	1	5	1
15. Chemical nomenclature.	0	3	1	0	4	1-2	5	1.3
16. Writing and balancing equations.	1	3	2	0	6	1-2	9	1.5
17. Graphical relationships.	0	1	0	1	2	1	2	1
18. Slide rule.	0	0	2	0	2	2-3	5	2.5
19. Prediction of common chemical reactions.	1	3	2	0	6	1	6	1
20. Percentage composition and stochiometric problems from chemical equations.	0	0	2	0	2	1	2	1

TABLE 44. (Continued)

Topic	Number of Institutions Responding: Univ.	Lib. Arts	Jr. Coll.	Spec.	Total	Range of Sessions per Topic (8 Syllabi)	Total Hours on Topic (8 Inst.)	Average Number of Hours per Topic
21. Colorimetry and problems on heat energy, specific heat, heating and cooling curves, heat of fusion, heat of vaporization, (Chemical Thermodynamics).	2	3	2	0	7	1-5	12	1.7
22. Hydrogen ion concentration and pH.	2	3	1	0	6	1-2	8	1.3
23. Colligative properties of solutions including freezing point depression and boiling point elevation.	1	3	1	0	5	1-3	10	2
24. Oxidation and reduction equations.	2	3	2	0	7	1-2	8	1.1
25. Writing of ionic equations, prediction of ionic and redox equations.	2	3	1	0	6	1-2	8	1.3
26. Electrochemical and electrolytic cells.	2	3	1	0	6	1-2	7	1.2
27. Writing nuclear equations and energy changes in nuclear reactions, half-life.	0	3	0	0	3	1-2	4	1.3
28. Reading Assignment.	1	0	0	0	1	15	15	15
29. Atomic Structure and Quantum Theory.	1	0	0	0	1	4		4
30. Solids.[b]	2	0	0	0	2	2-3	5	2.5
31. Chemical Kinetics.	1	0	0	0	1	3	3	3
32. Reaction Rates.	1	3	0	0	4	2	8	2
33. Cation Analysis.	1	1	0	0	2	1-3	4	2
34. Organic Chemistry.	0	1	1	0	2	1-3	4	2
35. Periodic Properties.[c]	3	3	0	0	6	1-9	28	4.7
36. Chemical Bonds.[d]	1	1	0	0	2	1-3	4	2

[a]Measurement, metric systems, temperature scales, exponential notations, significant figures, and logarithms.

[b]Crystals, lattice type, lattice energy.

[c]Periodic relationships and properties; transistion metal and coordination compounds.

[d]Valence Bond Theory, bond energies, bond lengths, polarity, geometry, resonance.

their own laboratory texts)[202] and eight professors listed supplementary reading materials (books, paperbacks, and departmental supplements). (Two respondents indicated that their respective departments had written their own course supplements or specific articles which were specifically designed for student assistance). A list of the textbooks, supplementary readings, and laboratory manuals used by the responding institutions is tabulated in Table 45 for reader interest and not for statistical justification. (The percentage use of the textbooks is not listed since less than 10 per cent of the professors mentioned the titles of the lecture textbooks and less than four per cent mentioned the names of the laboratory manuals). The data in Table 45 reveal the following use of lecture and laboratory reading materials: 18 textbooks (14 different titles) from 18 institutions; 24 supplementary books from eight institutions; and 11 laboratory manuals (three were staff prepared) from 10 institutions (only six of these sent syllabi which described their laboratory procedure and activities).

The reader is referred to an article entitled "Chemical Publishers Push Teaching Aids" (See Appendix "F") for a brief review of a few of the best-selling general chemistry textbooks and a discussion of the systems or "package" approach to teaching freshman chemistry.

Only six of the 15 responding institutions included an outline of

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[202] Additional comments to the questionnaire indicated that one department used a laboratory manual published by a commercial publisher; another stated that their department was encouraged to pursue AC_3 experiments; and another remarked, "Our course is an 'introduction to Scientific Laboratory' in which the students learn to make precise measurements with first class equipment, the specific skills learned are considered secondary," and a fourth professor mentioned that the laboratory manual was supplemented.

TABLE 45. TEXTBOOKS, SUPPLEMENTARY TEXTBOOKS, AND LABORATORY MANUALS.

Author	Title	Publisher and Date
Main Textbooks		
Audrey Companion	Chemical Bonding	McGraw Hill, 1964
Harry B. Gray and G. P. Haight, Jr.	Basic Principles of Chemistry	W. A. Benjamin Co.
Donald C. Gregg	Principles of Chemistry	Allyn and Bacon, 2nd ed., 1963
Morris Hein	Foundation of College Chemistry	Dickinson Publishing Co., Inc., 1st ed., 1967
J. H. Hildebrand and R. E. Powell	Principles of Chemistry	Macmillan Co., 1964
G. Brooks King and W. E. Caldwell	College Chemistry	American Book Company
Bruce Mahan	College Chemistry	Addison-Wesley Publishing Company
Bruce Mahan	University Chemistry	Addison-Wesley Publishing Co., 1st ed., 1965
W. L. Masterson and E. J. Slowinski	Chemical Principles	W. B. Saunders, 1966
William H. Nebergall, et al.	General Chemistry	D. C. Heath and Company, 1963
Rodney L. Olsen	Inorganic Nomenclature	Burgess Publishing Company, 1st ed., 1967
S. Young Tyree and Kerro Knox	Textbook of Inorganic Chemistry	Macmillan Company, 1961
J. Nelson Shaw	College Chemistry	Charles E. Merrill Books, Inc., 1966
M. J. Sienko and R. A. Plane	Chemistry	McGraw Hill Book Co., 3rd ed., 1966
Supplements		
W. E. Addison	Structural Principles of Inorganic Compounds	Wiley, 1961
Allen J. Bard	Chemical Equilibrium	Harper and Row, 1966
Gordon Barrow	Structure of Molecules	W. A. Benjamin Publishing Company
Gordon Barrow, et al.	Understanding Chemistry	Volumes I-V, W. A. Benjamin, Inc., 1967
Robert Bauman	Introduction to Equilibrium Thermodynamics	Prentice-Hall, Inc.
Bradner and Susskind	Atoms and Energy	Litton Instructional Materials, 1966

TABLE 45. (Continued)

Author	Title	Publisher and Date
Bradner and Susskind	The Electromagnetic Spectrum	Litton Instructional Materials, 1966
Herman T. Briscoe	College Chemistry	Houghton, 1951
James N. Butler	pH and Solubility Calculation	Addison Wesley, 1964
Gregory Choppin	Nuclei and Radio-activity	W. A. Benjamin, Inc., 1964
C. E. Dull, et al.	Modern Chemistry	Holt, Rinehart and Winston, 1962
Harry B. Gray	Electrons and Chemical Bonding	W. A. Benjamin, Inc., paperback ed., 1964
Robin M. Hochstrasser	Behavior of Electrons in Atoms	W. A. Benjamin, Inc., paperback ed., 1964
Edward L. King	How Chemical Reactions Occur	W. A. Benjamin, 1963
J. J. Lagowski	The Structure of Atoms	Houghton Mifflin, 1964
Charles E. Mortimer	Chemistry-A Conceptual Approach	Reinhold Publishing Co., 1967
W. C. Pierce, E. L. Haenisch, and D. T. Sawyer	Quantitative Analysis	John Wiley and Sons, 1958
Beckman Schaum and Joel L. Rosenberg	Theory and Problems of College Chemistry	Schaum Publishing Co., 1958
Glenn T. Seaborg	Man-Made Transuranium Elements	Prentice-Hall, Inc., 1963
D. K. Sebera	Electronic Structure and Chemical Bonding	Blaidsell, 1964
Michell J. Sienko	Equilibrium: Freshman Chemistry Problems and How to Solve Them	W. A. Benjamin, 1964
Staff Prepared (5)	Chemistry Supplements and Problem Books	
Jurg Waser	Basic Chemical Thermodynamics	W. A. Benjamin, 1966
Jay A. Young	General Chemistry	Prentice-Hall, 1963
Laboratory Manuals		
W. M. Latimer and R. E. Powell	A Laboratory Course In General Chemistry	Mcmillan, 1964
Lawrence E. Conroy and R. S. Tobias	General Chemistry Laboratory Operations	Macmillan, 1965
Harper W. Frantz	Laboratory Study of Chemical Principles	W. H. Freeman and Co., Second ed., 1956

TABLE 45. (Continued)

Author	Title	Publisher and Date
Lloyd E. Malm and Harper W. Frantz	College Chemistry in the Laboratory	W. H. Freeman and Co., #1 (1950) and #2 (1954)
Martin V. McGill and G. M. Bradbury	Chemistry Guide and Laboratory Activities	Lyons and Carnahan, 1964
W. C. Pierce, E. L. Haenisch, and D. T. Sawyer	Quantitative Analysis	John Wiley and Sons, 4th ed., 1958
C. H. Sorum	Introduction to Semi-micro Qualitative Analysis	Prentice-Hall, 4th ed., 1967
Staff prepared	Laboratory Experiments for Chemistry	
Staff prepared	Laboratory Manual	
Staff prepared	Laboratory Manual for Chemistry	
George W. Watt, et al.	Chemistry in the Laboratory	W. W. Norton and Co., Inc. 1964

their laboratory offerings and these syllabi gave a variety of laboratory experiences as evidenced by the data in Table 46. These data reveal that each of the six responding colleges is teaching its own individual laboratory course. The differences in choices of laboratory experiments and the schedule sequence in which they occur indicates variety. Since the response to the survey is so low with respect to the description of laboratory activities, the investigator believes that a study of laboratory experiments at the introductory level is needed since laboratory experiments should be an integral part of the first-year college chemistry course. The return of only six syllabi[203] from a total of 212 responding institutions is insignificant. The investigator believes, however, that

[203] These data in Table 45 reflect the titles of laboratory texts from ten colleges, but only six syllabi were used, since the other four colleges listed titles of the laboratory manuals, but did not send description of activities.

TABLE 46. LABORATORY EXPERIMENTS IN INTRODUCTORY COLLEGE CHEMISTRY

Assignment	Title of Experiments	Lab Periods in Weeks Devoted to Experiment
1	1. Analytical Balance.	1
	2. Slide Rule Instruction.	1
	3. Introductory Laboratory Technique.	1
	4. Weights and measurement plus unknown.	1
	5. Bunsen Burner, metric system.	1
	6. Laboratory techniques, metric system, and indirect measurement.	1
2	1. Laboratory burner, glassworking, determination of a chemical formula.	1
	2. Physical properties of substances and the analytical balance.	1
	3. Glassworking.	1
	4. Separation and determination of the components of a mixture.	1
	5. Density, physical and chemical properties.	1
	6. Separating mixtures, breaking up compounds, physical and chemical change, Law of Conservation of Energy, and change in heated metals.	1
3	1. Law of DuLong and Petit.	1
	2. Chemical properties of substances and unknown weights.	1
	3. Percent composition.	1
	4. Observing reactions and breaking up compounds.	1
	5. Starting growth of crystals.	1
	6. Analysis of an iron solution.	1
4	1. Chemical and physical changes.	1
	2. Molal volume of a gas.	1
	3. Molal volume of nitrogen.	2
	4. Growth of an alum crystal.	1
	5. Preparation and properties of oxygen.	1
	6. Identification of salts by use of reaction rules.	1
5	1. Law of multiple proportions.	1
	2. Molecular weight by vapor density.	2
	3. Molecular weight of a gas.	1
	4. Preparation and study of oxygen, oxygen generation and composition of air.	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Lab Periods in Weeks Devoted to Experiment
	5. Charles' Law and Option.	1
	6. Chemical reaction and chemical equation.	1
6	1. Calculations involving redox reactions.	1
	2. Reduction of oxides.	1
	3. The equivalent weight of a metal.	1
	4. Preparation and properties of hydrogen and reaction rates.	1
	5. Acid, Base, or Salt?	1
	6. Diffusion of gases.	1
7	1. Boyle's Law and Graham's Law of Diffusion.	1
	2. Makeup labs and help sessions.	1
	3. Unknown equivalent weight.	1
	4. Relative activities of some of the metals.	1
	5. Common chemical reactions.	1
	6. Hydrogen and its properties.	1
8	1. Molecular weight of carbon dioxide.	1
	2. Atomic weight, specific heat, and equivalent weight.	1
	3. The packing of atoms and ions in a crystal.	1
	4. Water of hydration of $BaCl_2$, including option or unknown.	1
	5. Common chemical reactions.	1
	6. The formula of tin oxide.	1
9	1. Vapor pressure of a liquid.	1
	2. Freezing point of a solution.	3
	3. Ionic and covalent compounds.	1
	4. A study of hydrates, percent water of hydration.	1
	5. Solubility curve of NaCe.	1
	6. Anhydrides, acid and base, supersaturated solutions.	1
10	1. Molecular weight from freezing point depression.	1
	2. Pure substances and mixtures, melting points.	1
	3. Preparation of pure substances.	3
	4. Strong acid-base titration.	1
	5. Titration of vinegar (unknown).	1
	6. Determination of weight of hydrogen and equivalent weight of magnesium.	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Lab Periods in Weeks Devoted to Experiment
11	1. Group I - known and unknown.	1
	2. Radioactivity.	1
	3. Determination of the forms of a compound.	1
	4. Getting substances to dissolve, acid and bases, conductivity of solutions and completion reactions.	1
	5. The effect of temperature changes on the volume of a gas at STP.	1
12	1. Titration of vinegar, hydrolysis, electrolytes.	1
	2. Preliminary qualitative analysis and unknown.	2
	3. Flame tes's and Group IV.	1
	4. Titration.	2
	5. Chemistry of compounds of nitrogen.	1
	6. Titration experiment.	1
13	1. Titration of acids and bases.	1
	2. Organic models.	1
	3. Test for halides, study properties of iodine and chlorine.	1
	4. Anions - preparation.	1
	5. The Seven-Bottle Experiment-J. Chem. Educ.	1
	6. Group II Anions.	2
14	1. Qualitative analysis "known."	1
	2. Properties of sulfuric acid.	1
	3. Preparation of a salt.	1
	4. Organic chemistry.	1
	5. Group I Anions.	2
	6. Group II Anions.	1
15	1. Qualitative analysis "unknowns."	1
	2. Flame tests.	1
	3. Chemical equilibrium and reaction rates.	1
	4. Building structural models of organic compounds.	1
	5. General anion unknown.	1
	6. Oxidation and reduction.	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Lab Periods in Weeks Devoted to Experiment
16	1. Unknowns equivalent weight of a solid acid.	1
	2. Semimicro qualitative analysis.	15 weeks
17	1. Oxidation and reduction.	2 weeks
	2. Solubility and rate of solution.	2
18	1. Titration involving oxidizing and reducing agents.	2
	2. Solubility of NaCe in water.	1
19	1. Production of an electric current by means of oxidation-reduction reaction.	1
	2. The preparation and coagulation of colloids.	1
20	1. pH meter and indicator.	1
	2. The organic acid content of commercial vinegar.	1
21	1. Unknown--pH meter and indicator.	1
	2. The ammonia content of "Household Ammonia."	1
22	1. Reversible reactions and equilibrium.	2
	2. Chemical analysis.	1
23	1. Ionization constant of a weak acid.	1
	2. Paper chromatographic analysis.	1
24	1. Equilibria - Ions of water, pH, hydrolysis.	1
	2. The qualitative analysis of baking powder.	1
25	1. Solubility product of a slightly soluble salt.	1
	2. Alcohol fermentation.	1
26	1. Some elementary experiments in organic chemistry.	1
	2. Removal of stains from fabrics.	1

these few practices to be varied enough to justify the statement for the need of a study of laboratory practices.

The Journal of Chemical Education (September issue each year) and Chemical and Engineering News[204] reveal that scores of introductory college chemistry textbooks of varying difficulty have been recently written or revised.

The investigator's review[205] of these aforementioned books shows topics to be presented at different levels of difficulty and in random sequence of arrangements. A logical sequence of topics is apparently difficult to ascertain, and the amount of time devoted to a given topic is probably related to the textbook author's specific interest or to the instructor's personal interest. To teach all the facts of chemistry is an impossibility; however, a careful selection of topics with a conceptual scheme illustrating the processes of chemistry could possibly add structure to first-year college chemistry.

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[204] "Chemical Publishers Push Teaching Aids," Chemical and Engineering News, 46, August 19, 1968, pp. 32-35.

[205] B. C. Dodson and George Castleberry, "A Comparison of the One-Year High School and the Freshman College General Chemistry Textbooks," An unpublished survey performed under the direction of Dr. John W. Renner, University of Oklahoma, Norman, 1966.

CHAPTER IX

SUMMARY AND GENERAL FINDINGS

The problem is restated here in the form of a question which is answered by the presentation of a summary of the data assembled from the different parts of the completed questionnaires received from the accredited colleges and universities teaching introductory college chemistry: What are the present objectives, teaching methods, and materials used in teaching the introductory course in college chemistry in selected accredited colleges and universities in the continental United States?

A survey of the data in the previous chapters reveals the following facts:

(1) The general objectives and aims of the introductory college chemistry course are: (a) to develop the ability to do critical thinking, (b) to make the students familiar with the facts, principles, and concepts of chemistry, (c) to help the student understand the nature of matter and its transformation, (d) to develop the ability to handle quantitative problems, (e) to develop intellectual honesty rather than foster the search for the "right" answer, and (f) to teach students to be precise in observation and expression. (Chapter V).

(2) A great variation in the titles as well as in the description of the introductory college chemistry course is evident; however, the term "General Chemistry" still prevails as the choice course name. (Chapter IV).

(3) This is a diversity evident by the listings of 35 course prerequisites with 39 percent of the courses offered requiring no prerequisite. (Chapter IV).

(4) The course credits range from 2 to 12 semester hours per year. The mean semester hour average for universities is 13.8; for liberal arts colleges is 10.2; for junior colleges is 11.2; and for specialized institutions is 12.0. The average number of courses offered per institution is 1.6 and the average number of semester hours credited alloted per college per year is 11.9, while the average number of semester hours assigned per course in all institutions surveyed is 7.3. (Chapter IV).

(5) The average number of college professors per university is less than six; less than three per liberal arts college and junior colleges; and four for each specialized institution. The fact that 89 percent of the universities, 76 percent of liberal arts colleges, 18 percent of junior colleges and 52 percent of specialized institution professors have earned Ph.D. degrees in chemistry is encouraging, but all classifications of institutions are in need of more professors with earned doctorates. This is especially at the junior college level. (Chapter IV).

(6) College professors need more student assistants as evidenced by an approximate average of 15, 5, 3, and 5 student assistants per college for universities, liberal arts colleges, junior colleges, and specialized institutions, respectively. The quality of help is probably less than desired since 31 percent of the student assistants have no college degree, and 49 percent have only earned a BS degree. (Chapter IV).

(7) The general practice of college professors during the past two years is to change the textbook and laboratory exercises, but to adhere

to the same course outline, as shown by an 82 percent positive indication of change. (Chapter V).

(8) Fifty-nine percent of the 212 institutions pay no attention to the chemistry background of the student, and the practice is to place all students in the same first-year college chemistry course. (Chapter IV).

(9) The consensus of a majority of the professors is that a course be offered in chemical properties with descriptive parts of the course used both to illustrate principles and to show how principles are derived. (Chapter IV).

(10) By a 56 percent approval college professors indicated a possible acceptance of the use of a combination of staff prepared and commercially prepared laboratory manual and textbook material. (Chapter V).

(11) The data show that college professors are not utilizing the modern teaching aids as suggested by the Advisory Council on College Chemistry. (Chapter V).

(12) The teaching primary method favored, other than lecture, is regular problem assignments. (Chapter V).

(13) University teachers make more use of conference quizzes, and the junior colleges offer more self-assistance to students than do other categories of institutions. (Chapter V).

(14) There is a low percent use of equipment other than the single pan balance, the spectrophotometer, and the pH meter. These findings contradict the recommendations of AC_3. (Chapter V).

(15) All institutions rejected the practice of stating objectives and the ensuing preparation of tests or other means of evaluating whether these objectives had been achieved, as revealed by a 42 percent and a

19 percent reply. (Chapter V).

(16) The more popular methods used to evaluate the success of the introductory college chemistry course are subjective observations, special examinations, and discussion involving the entire chemistry faculty. (Chapter V).

(17) Although textbook changes were frequently made (see number "7"), the previously stated course objectives have been changed very little, as shown by a 64 percent negative reply to a statement requesting an indication of a substantial change in course objectives when a new course replaced an older course. (Chapter V).

(18) Some colleges and universities are providing a variety of methods to challenge superior or talented students. These methods include (1) honors courses, (2) independent study, (3) advanced placement, (4) conference study, and (5) testing out. (Chapter V).

(19) The professors listed 26 various reasons for changing the introductory college chemistry course. The foremost change factors are: (a) theories of chemistry are constantly changing, (b) more equipment and more modern equipment are available for laboratory and instructional use, (c) advent of general chemistry textbooks with a change in emphasis, and (d) the large number of students beginning the study of first-year college chemistry who are better prepared in terms of high school chemistry and mathematics. (Chapter VII).

(20) The data from teacher reactions to factors that college professors believe to reduce student interest in freshman chemistry indicate the need for chemistry educators to take a look at their pedagogical practices and develop some methods and techniques to increase student

interest in topics. College professors believe the major reason for reduction of student interest is that topics are unrelated to student interest. (Chapter VII).

(21) The data and additional information related to factors that college professors believe to reduce student interest and teacher reactions to a pre-selected list of suggestions with respect to develop improved teaching gave sufficient evidence to justify a revolution in attitudes and methods of teaching and in the methods of educating college teachers of chemistry even to the point of retraining those people already engaged in the teaching of first-year college chemistry. The implication is very strong that there is a need to teach introductory college chemistry as a process is indicated by an 85 percent approval of all professors in Table 42. (Chapter VII).

(22) College chemistry professors have either rejected and/or do not have time to prepare a course outline or syllabus. Chemistry professors, in general, do not state course objectives and the most typical course evaluation is a subjective evaluation. (Chapter V).

The 60 percent response to the survey constitutes a rather full and complete analysis of the teaching practices in introductory college chemistry.

CHAPTER X

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following profile is constructed from the survey data to reflect the diversity in regard to the manner in which first-year college chemistry is being taught: (1) Numerous changes have taken place in freshman chemistry as evidenced by the variety of titles used to describe the courses offered; (2) The course prerequisites vary widely as to nature and difficulty within and between institutions; (3) College professors accepted, as evidenced by an affirmative reply of 93 per cent, the general objective of first-year college chemistry to be the development of the ability to do critical thinking. But only 41 per cent agree that the course should be taught from textbooks of varying difficulty and utilizing the inquiry approach; (4) A variety of responses resulted from the request for an opinion as to what the first college course in chemistry should be; the majority opinion indicating a greater emphasis be devoted to descriptive topics; (5) There are no standard methods of handling experimental data as evidenced by a listing of nine methods for collecting data and 29 methods used to record data; (6) College professors are not utilizing the modern teaching aids suggested by AC_3; (7) The evidence suggests that a change is needed in teacher attitudes and methods as well as a change in the method of educating chemistry teachers; (8) A majority of the institutions (59 per cent) retain the practice of

placing all students in the same course with little indication of an evaluation of a student's academic preparation. (See pp. 82, 95, 168 and 111, 116, pp. 135 and 139, p. 180, p. 211, and pp. 105-106).

Recommendation

The investigator is of the opinion that some of the controversy in introductory college chemistry could possibly be resolved by some national organization sponsoring a curriculum study and writing conference similar to the Biological Science Study Committee (BSCS). The survey findings, AC_3 publications, the Systems approach, and the Hammond Curriculum might serve as a guideline to the synthesis of some new chemistry innovations in first-year college chemistry. The investigator suggests a minimum of three courses of varying difficulty and goals--one for the general education major, one for the physical science major, and one for the biological science major; still another could be designed for the talented student. (There is some doubt that three courses could fit the diverse needs of the different institutions but three such courses should offer a justly improved point of departure from those presently available. Another problem would be found in selecting an approach to teaching the course which would satisfy a large number of professors). Specific attention should be directed to learning of chemistry concepts and the development of a sequential arrangement of topics based upon a conceptual framework. The selection of course topics and the sequential arrangement of topics in a logical manner merits the assistance of educators who know about learning and concept development. Behavioral objectives must be stated and teaching methodology to stimulate student interest must be an integral part of each course. A writing conference could utilize the experiences and capabilities of the numerous and experienced and success-

ful teachers and authors of first-year college chemistry textbooks and laboratory experiments. Trial centers should be set up so that each separate course would be tested by college and university chemistry professors. Methods to evaluate student progress and also the success of a given course must be designed, tested, and retested. The investigator believes that these courses (when designed, developed, and tested) will challenge the varying abilities of a disparate student population and will be commensurate with an individual student's academic preparation and would correlate with his vocational plans. Special interest topics could be written to supplement these courses and challenge students.

Suggested Research

The present survey does not give enough data on course outlines and syllabi, and laboratory experiments, including pre-laboratory sessions, to discern a trend; however, the data from Chapter VIII suggest that additional research is needed to describe the lecture and laboratory practices in general chemistry. The data also reflect the need of a study to determine the nature of the one-or-two hour sessions which are being devoted to problem sessions and/or problem discussions. How much time is devoted to problem sessions and what is the nature of these problem assignments?

A study is needed to determine how the teachers of first-year college chemistry are being educated with an ensuing objective of formulating guide lines for the proper education of future chemistry teachers. How much does a chemistry teacher know about learning and concept development? The survey findings on student and course evaluation, in the opinion of the investigator, are incomplete; another study on evaluation is needed.

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APPENDIX

APPENDIX A

STATISTICAL CALCULATIONS

STATISTICAL CALCULATIONS

The following formulas were adopted from William G. Cochran, Sampling Technique. New York: John Wiley and Sons, Inc., 1953, pages 74, 82, 88, and 89.

Theorem: In stratified random sampling, the variance of the estimated mean $\bar{y}_{st}$ is smallest, for a fixed total size of sample, if the sample is allocated with n_h proportional to N_hS_h.

Proof: The problem is to minimize

$$V(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} N_h(N_h - n_h) \frac{S_h^2}{n_h}$$

subject to the restriction

$$n_1 + n_2 + \dots + n_L = n$$

The n_h and the Lagrange multiplier λ are selected so as to minimize

$$V(\bar{y}_{st}) + \lambda(n_1 + n_2 + \dots + n_L - n)$$

$$= \frac{1}{N^2} \sum \left(\frac{N_h^2}{n_h} - N_h \right) S_h^2 + \lambda(n_1 + n_2 + \dots + n_L - n)$$

Differentiating with respect to n_h, the following equation is obtained

$$- \frac{N_h^2}{N^2} \frac{S_h^2}{n_h^2} + \lambda = 0 \qquad (1)$$

This gives

$$n_h = \frac{N_hS_h}{N\sqrt{\lambda}}, \text{ or } n_h \propto N_hS_h \qquad (2)$$

To find the actual value of n_h, add (1) over the strata. Thus

$$\Sigma\, n_h = n = \frac{N_h S_h}{N\sqrt{\lambda}} \tag{3}$$

Substitution for $\sqrt{\lambda}$ into (2) gives

$$n_h = n \frac{N_h S_h}{\Sigma\; N_h S_h} \tag{4}$$

This result states that the sample size in a stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or, in other words, that the sampling fraction n_h/N_h should be proportional to the standard deviation. Other things being equal, a larger sample is needed in a variable stratum.

An expression for the minimum variance is obtained by substituting the values of n_h given by (4) into the general formula for $V(\bar{y}_{st})$. This gives

$$V \min (\bar{Y}_{st}) = \frac{1}{N^2} \frac{(\Sigma\, N_h S_h)^2}{n} - \frac{1}{N^2} \Sigma\; N_h\, S_h^{\,2} \tag{5}$$

If $\underline{V}$ is the desired variance for the estimated population <u>total</u>, the principal formula becomes as follows:

<u>Presumed optimum</u> (for fixed n):

$$n = \frac{(\;\Sigma \quad N_h S_h)^2}{V + \Sigma\; N_h S_h^2} \tag{6}$$

APPENDIX B

QUESTIONNAIRE

5

SOUTHERN STATE COLLEGE

MAGNOLIA, ARKANSAS

Dear Colleague:

You are invited to assist in a survey of the objectives, teaching methods, and materials used in the teaching of the introductory course in college chemistry. This research is supported by the United States Department of Health, Education, and Welfare, proposal number 7G018.

The purpose of the survey is to determine using a wide scale sample what objectives, teaching methods, and materials are used in the introductory chemistry course in accredited colleges and universities. This questionnaire calls for facts concerning the teaching of introductory college chemistry in your institution. Completion of this questionnaire may appear to be quite a task, but for the most part it is a check list. This questionnaire also refers to courses which give credit under the title, "Chemistry." The questionnaire is not particularly concerned with those courses designed for non-science majors or for physical science credit and the like that do not meet prerequisite requirements for further courses in your curriculum. If you do not teach in the introductory college chemistry course, will you kindly pass this questionnaire to the person who does.

You are no doubt interested in learning what is being taught in the introductory college chemistry courses. A copy of the abstract of the study will be sent to you for your most gracious assistance.

A stamped, self-addressed envelope is enclosed for your convenience. Please return the questionnaire as soon as possible. Thank you for your cooperation in this matter.

Cordially yours,

B C Dodson

B. C. Dodson
Head of Chemistry Department

BCD/bp
Encl.

QUESTIONNAIRE

PART I

INFORMATION ON INTRODUCTORY COLLEGE CHEMISTRY COURSES

1. Please list the titles of the introductory college chemistry courses offered under the title "Chemistry" in your institution or attach pages from the college catalog listing these. (Omit non-science chemistry courses or pre-nursing courses and the like that do not meet prerequisite requirements for further coures in your chemistry curriculum.)

Course Number	Course Title	Course Enrollment Per Year	Pre-requisite(s)	Credit (Semester Hrs.)

2. Approximately what percent of the students in these courses have had some previous chemistry? (Please give approximate percentages, not numbers.)

_____ have had no chemistry

_____ have had a traditional high school chemistry course

_____ have had Chems or CBA

3. Approximately what percent of the students in these courses eventually major in chemistry? (Please give percent, not numbers.) _______________

4. Faculty Personnel:

	Field of Highest Degree (Chem., Educ., etc.)	Highest Degree B.S.	M. S.	Ph.D.
Name of Professor in charge of introductory college chemistry: __________	__________	( )	( )	( )
Number of other professors that teach lecture or laboratory sections of introductory chem.: (Place number in bracket with each degree.)				
__________	__________	( )	( )	( )
__________	__________	( )	( )	( )

Number of student assistants: _____ Highest Degrees of these student assistants: (Place number in bracket with each degree.)

No Degree ( )

( ) ( ) ( )

Responsibility: ( ) lecture ( ) laboratory ( ) other (specify) __________

5. Check the classification of your college or university:

( ) a. Junior College

( ) b. College of Liberal Arts

( ) c. Specialized Institution

( ) d. University

CLASSIFICATION SCHEME: Junior College is an institution offering a two year program of study beyond the level of the secondary school, and this college work can be transferred to a baccalaureate degree. College of Liberal Arts refers to those institutions in which the principal emphasis is placed on the program of general undergraduate education. Specialized Institution is the category which includes schools that offer degree programs directed toward one or more fields of specialization that are not attached to a liberal arts college or university. They are principally schools of technology, teacher training, theological schools, etc. University refers to those institutions in which there is considerable stress on graduate instruction, which confers advanced degrees in schools that are not exclusively technological.

6. Is your chemistry department accredited by the American Chemical Society?

( ) Yes

( ) No

7. What is the typical course(s) that you offer students entering the introductory chemistry course?
(Check all statements that pertain; respond only to those statements that apply to your institution.)

( ) a. No distinction as to chemistry background. All students take same course.
( ) b. Course is designed in such a way that the better prepared student can complete the equivalent of one year course in one semester.
( ) c. Place all students together but compensate for the student who has had no prior study in chemistry by using some of the early laboratory periods as drill sessions to give students experience in momenclature, elementary facts of atomic theory, and equation writing. Are these sessions extra _____ or regular _____?
( ) d. Selected students are given a brief review and then placed in an honors section by examination.
( ) e. Offer several introductory chemistry courses of varying difficulty; how many such courses _______?
( ) f. Give a sufficiently different course in the laboratory such that no student feels he is repeating the course. Try to eliminate trivia and introduce advanced and non-traditional topics.
( ) g. Other (Specify) ____

____

8. Complete this section only if you teach an "honors" course. If you have no honors course check here ( ).

A. What description best fits the nature of the course? (Check only one)
( ) 1. One which omits descriptive inorganic and schematic scheme of analysis.
( ) 2. A one semester course followed by thermodynamics.
( ) 3. A course in chemical principles with descriptive chemistry.
( ) 4. A course comprising largely organic chemistry.
( ) 5. A combined chemistry-physics course.
( ) 6. A course in crystal structure.
( ) 7. Other (Specify) ______________________________

B. What methods are used for selecting the students? (Check all statements that pertain.)
( ) 1. Placement Examination
( ) 2. College Board Examination
( ) 3. Special Examinations (______________________)
( ) 4. High School Science Background
( ) 5. High School Record
( ) 6. American College Testing Program (ACTP)
( ) 7. American Chemical Society Examination
( ) 8. ACT Grade in Mathematics
( ) 9. High School Chemistry Grade
( ) 10. Other (Specify) ______________________________

Rank the above methods in the importance attached to the selection of students by placing your choice of 1, 2, 3, 4, to the left of the checks.

C. Which of these best describes the suitability of the "available" textbooks for this course or independent study? (Choose One)
( ) 1. Suitable textbooks and laboratory manuals are available.
( ) 2. None of the existing textbooks or laboratory manuals suit our purpose.
( ) 3. Other (Specify) ______________________________

9. In this investigation the majority of the currently available textbooks and laboratory manuals are considered as representing the "conventional" course. Please react to the following six statements about the conventional course. If you agree with the statement, encircle "A". If you disagree with the statement, encircle "D". If you are undecided about the statement, encircle "U".

The "conventional" course in college chemistry:

1. is generally satisfactory for all students.	A	D	U
2. is more appropriate for students who major in chemistry than those who do not.	A	D	U
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	A	D	U
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry	A	D	U
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	A	D	U

6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to C.B.A. and CHEM study at the introductory college level. A D U

10. Which of these best describes the laboratory manual or text that you use in the introductory college chemistry course? (check one)

( ) a. Only materials prepared by the chemistry staff.
( ) b. Only published material which is available commercially.
( ) c. A combination of the above.
( ) d. Other (specify) ____________________

11. What type of pre-laboratory instruction do you give the introductory college chemistry students? (Please check all that apply.)

( ) a. Students are expected to have read directions.
( ) b. Students are assigned supplementary readings other than laboratory manual directions.
( ) c. A pre-laboratory drill assures that students have read directions.
( ) d. A pre-laboratory quiz assures that students have read directions.
( ) e. A pre-laboratory quiz assures that students have read supplementary readings.
( ) f. A pre-laboratory quiz assures that students have worked the drill.
( ) g. The experiment is demonstrated.
( ) h. Procedure is discussed.
( ) i. The theoretical basis of the experiment is discussed.
( ) j. Questions are answered.
( ) k. Special emphases and different points are elucidated.
( ) l. Other (please specify) ____________________

12. How do your introductory chemistry students handle experimental data? (Check one)
( ) a. Data is recorded in duplicate by use of carbon paper.
( ) b. Data is recorded on blank separate sheets.
( ) c. Data is recorded in blank notebooks.
( ) d. Data is recorded on special printed forms you provide separately.
( ) e. Other (specify ____________________

13. What type of reporting do you expect from the introductory chemistry students? (Please check all that apply.)
( ) a. Fill in data and results on printed sheets.
( ) b. Students design their own report sheets.
( ) c. Full reports (essay form).
( ) d. Sample calculations only.
( ) e. Full calculations.
( ) f. Duplicate raw data sheets (carbon paper record).
( ) g. Supplementary questions are answered in the laboratory.
( ) h. Graphs from data in the laboratory.
( ) i. Other (Specify) ____________________

14. Do your introductory students perform special projects? ( ) yes ( ) no
If yes, approximately what percent of the laboratory course is taken up with them? __________ percent

15. Excluding the honors course or specialized course, how are you challenging the superior student who has successfully completed high school chemistry, and in addition, shows special talent? (Check all statements that pertain to your institution.)

A. No provisions made, because-
( ) 1. No interest.
( ) 2. Lack of student time.
( ) 3. Lack of professor time.
( ) 4. Lack of facilities.
( ) 5. Do not have, but are interested.
( ) 6. Other (Specify)________________________________

B. Independent Study: (The student carries on a study of basic research under the direction of a faculty member and prepares a paper on his work in the manner of a journal article.) The nature of this independent study is a -
( ) 1. Special laboratory project.
( ) 2. Special problem in qualitative analysis.
( ) 3. Special problem selected by the individual student.
( ) 4. Special problem selected by the chemistry department.
( ) 5. Do not have, but are interested.
( ) 6. No interest.
( ) 7. Other (Specify) ________________________________

C. Conference Study or Conference Sessions: (Informal meetings on a variety of topics-freshman presentation.)
( ) 1. Seminar.
( ) 2. Assist professors or graduate students in preparing papers to be presented at seminars.
( ) 3. Other (Specify) ________________________________

D. Advanced Placement ( ). Describe ________________________________

16. Answer parts (A) and (B): then complete this section only if your department has in the last two years revised its old course and/or added a new course.

A. Has your department added a new introductory chemistry course in the last two years?
( ) 1. Yes
( ) 2. No

B. Has your department made such changes as textbook change or revision and/or laboratory exercise changes or revision in the introductory chemistry course in the last two years?
( ) 1. Yes
( ) 2. No

C. If your answer to either 16-A or 16-B is Yes, please answer the following questions by encircling "Y" if your answer is Yes; encircle "N" if your answer is No; and encircle "U" if you are Uncertain.
1. Have the content and program of instruction been considerably modified but the framework of the old course retained? Y N U

2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course? Y N U
3. Are you using an outline or syllabus which was prepared especially for the new course? Y N U
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units? Y N U
5. Do you expect more reading outside the text in the new or revised course than in the old course? Y N U
6. Is the work in the new or revised course independent of collaboration with physicists? Y N U
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory? Y N U
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course? Y N U
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access? Y N U
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course? Y N U

17. Which of the following best represents your opinion of what the introductory course in college chemistry should be? (Choose only one.)

( ) 1. A course in chemical principles with descriptive chemistry serving only to illustrate these concepts.

( ) 2. A course based heavily on laboratory and classroom demonstration of a phenomenon.

( ) 3. An integrated course in physics, chemistry, and mathematics.

( ) 4. An inventory of factual materials and phenomenological formulas needed for advanced study.

( ) 5. Other (Specify) ______________________________

PART II

OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Indicate by encircling the letter "A" those objectives which you believe to be very important; encircle "S" those objectives which you believe to have some importance; and encircle the letter "D" those which you believe are not at all important.

Which of the following do you believe to be the most significant aims and objectives which the study of introductory college chemistry should allow a student to achieve? (Respond to each statement)

1. Show the relationship of chemistry to other sciences.	A	S	D
2. Help the student to understand the nature of matter and its transformations.	A	S	D
3. Develop the ability to do critical thinking.	A	S	D
4. Make students familiar with the facts, principles, and concepts of chemistry.	A	S	D
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	A	S	D
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	A	S	D
7. Give students an idea of the importance and significance of chemistry in our national life.	A	S	D
8. Development of specific interests, habits, and abilities which should be contributed to by all courses in science.	A	S	D
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	A	S	D
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks.)	A	S	D
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	A	S	D
12. Teach students to be precise in observation and expression.	A	S	D
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	A	S	D
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrevelant data.	A	S	D
15. Formulate, as well as answer, questions.	A	S	D
16. Develop intellectual honesty rather than foster the search for the "right" answers.	A	S	D
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	A	S	D
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	A	S	D
19. Provide the student direct experiences related to concepts expounded in the classroom.	A	S	D
20. Demonstrate the extension of human sensory perception by appropriate instruments.	A	S	D
21. Develop selected manipulatory skills involved in laboratory techniques.	A	S	D

22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there. A S D

23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature. A S D

24. Other (Specify) ______________________

25. What five of the above statements (1-24) do you consider to be the most significant objectives of introductory chemistry? Rank these five choices in the most importance attached to course objectives by placing the number of the most important objectives in descending order from left to right: ______________________

26. How do you evaluate the success of the introductory chemistry course in your institution? (Check all that apply)
( ) 1. Special examination.
( ) 2. Subjective observations.
( ) 3. By using a student-completed questionnaire.
( ) 4. Discussion involving the entire chemistry faculty.
( ) 5. No evaluation.
( ) 6. Other (Specify) ______________________
Indicate a periodic or spasmodic evaluation by placing a "p" or an "s" at the end of the sentence of your choice.

PART III

SUPPLEMENTARY MATERIALS, EQUIPMENT, AND METHODOLOGY USED IN THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Place a check mark in the box located to the left of those supplements that you use to assist you in teaching the introductory college chemistry course. Place a check in column "A" if supplements are used in the classroom by instructor and a check in column "B" those supplements used outside the classroom by students.

	Supplementary Materials	A	B
( )	1. Study guides prepared by the chemistry faculty.	____	____
( )	2. Student personal data inventories.	____	____
( )	3. File of previous given chemistry tests.	____	____
( )	4. Bibliography of reading materials for students	____	____
( )	5. Study Materials:		
	a. Articles	____	____
	b. Books	____	____
	c. Film Loops	____	____
	d. Programmed Materials	____	____
	e. Other (Specify) ______________________	____	____
( )	6. Atomic and molecular models.	____	____
( )	7. Visual aids.	____	____
	a. Filmstrips	____	____
	b. Overhead projector	____	____
	c. Opaque projector	____	____
	d. 8 mm or 16 mm projector	____	____
	e. Closed circuit television	____	____
	f. Other (Specify) ______________________	____	____
( )	8. Paperback books available in the college bookstore.	____	____
( )	9. Videotape.	____	____
( )	10. Computer assisted instruction.	____	____
( )	11. Other (Specify) ______________________	____	____

		Equipment Use		
	Equipment	Demonstration	Student Experiments	Study of Design
( )	12. Direct reading balances.	( )	( )	( )
( )	13. Gas Chromatograph.	( )	( )	( )
( )	14. Infra-red spectrophotometer.	( )	( )	( )
( )	15. Bausch and Lomb Spectronic 20.	( )	( )	( )
( )	16. PH Meter	( )	( )	( )
( )	17. Conductivity bridge.	( )	( )	( )
( )	18. Polarimeter.	( )	( )	( )
( )	19. Geiger counter or scintillator.	( )	( )	( )
( )	20. Paperchromatography.	( )	( )	( )
( )	21. Other (Specify) ______________________			

Outside Materials

( ) 22. Field trips, exploration trips, local industry, resource speakers (outside speakers.) Underscore those used.
( ) 23. Chemistry club and parties.
( ) 24. Other (Specify) ______________________________

Methodology and Techniques

( ) 25. Demonstrations (teacher and/or students).
( ) 26. Panel Discussions.
( ) 27. Team teaching and/or committee teaching.
( ) 28. Programmed instruction.
( ) 29. Review sessions and/or tutorial sessions.
( ) 30. Conference quizzes.
( ) 31. Series of quizzes, tests - objective and subjective.
( ) 32. Student conferences with faculty members.
( ) 33. Regular problem assignments.
( ) 34. Urge the students in class and out of class to use the library for other than textbook reading.
( ) 35. Require term papers on topics not adequately covered in textbooks or secondary sources.
( ) 36. Special topics and reports.
( ) 37. Student presentation of problems and solutions.
( ) 38. Assign research journal articles for reading.
( ) 39. Presenting the limited but useful aspects of "black box" instruments.
( ) 40. Let students plan, execute, and interpret experiments.
( ) 41. Using "open-ended" experiments.
( ) 42. Devise experiments so that original sources must be consulted.
( ) 43. Using some laboratory experiments which "stand on their own feet," i.e., experiments which are not dependent on materials discussed in the classroom. If not, why? ______________________________
( ) 44. Using simple "mock-up" rather than complex apparatus to concentrate the student's attention on ideas rather than manipulation.
( ) 45. Other (Specify) ______________________________

PART IV

FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE

What are the factors that tend to limit student interest in the introductory chemistry course?

( ) 1. Topics are unrelated to student interest.
( ) 2. Too much theory.
( ) 3. Not enough laboratory work.
( ) 4. Insufficient or inadequate laboratory equipment.
( ) 5. Lack of library facilities.
( ) 6. Not enough individual work.
( ) 7. Too much memory work.
( ) 8. Subject too formally presented.
( ) 9. Instructor teaching too many subjects or students.
( ) 10. Facts taught as ends (products) of science rather than a means (processes) of science.
( ) 11. Too much teacher dependence on textbook.
( ) 12. Too much telling - too teacher domination.
( ) 13. Failure of instructor to clarify a general principle.
( ) 14. Failure to use "practical tangibles" in place of "textbook tangibles."
( ) 15. Too little faculty time --too involved in research or other activities.
( ) 16. Poor instruction by graduate assistants.
( ) 17. Other (Specify) ____________________

PART V

REASONS FOR CHANGING THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

1. What do you consider as compelling reasons for considering course revision? (Check all statements that pertain.) Check here ( ) if you consider your present course satisfactory and no course revision is necessary.
   ( ) a. The availability of more equipment and more modern equipment for laboratory and instructional use.
   ( ) b. Impact of CBA, CHEMS, PSSC courses.
   ( ) c. The number of chemistry majors is diminishing.
   ( ) d. Theories of chemistry are constantly developing.
   ( ) e. Advent of general chemistry textbooks with a change in emphasis.
   ( ) f. Flood of new information appearing in the chemical literature.
   ( ) g. Large number of students beginning the study of introductory college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and/or mathematics.
   ( ) h. Other (Specify) ____________________

2. Rate these items as you believe they should be developed to improve the teaching of college chemistry at the introductory level. (Indicate by encircling "A" those things which you believe to be very important; encircle "S" those things which you believe to have some importance; and encircle "D" those things which you believe are not at all important.)

   A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests. A S D

B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as the content and the ability to do critical thinking. A S D

C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching. A S D

D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching techniques) and in the methods of educating college teachers of chemistry. A S D

E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten. A S D

F. Other (Specify) ______________________________

PART VI
ADDITIONAL INFORMATION

1. What other specific uses or additional information for which space and headings are not provided can you supply? Please feel free to add all you can. You may use the back of this page or attach a page. A syllabus of your introductory chemistry course or any other related material would be helpful to the study.

2. ______________________________
Name of person completing this questionnaire

( ) Professor
( ) Associate Professor
( ) Assistant Professor
( ) Instructor

Do you teach the course ? ( ) Yes ( ) No
If you do not, do you have any duties in connection with the course?
( ) Yes ( ) No
If yes, specify these duties: ______________________________

____
Name of Institution City State Zip Code

Return to B. C. Dodson, Chairman, Chemistry Department, Southern State College, Magnolia, Arkansas 71753

APPENDIX C

LIST OF INSTITUTIONS IN SAMPLE

UNIVERSITIES

Alabama, University of, Alabama
Alfred University, New York
Andrews University, Michigan
Arkansas, University of, Arkansas
Auburn University, Alabama
Baylor University, Texas
Boston University, Massachusetts
Bowling Green State University, Ohio
Bridgeport, University of, Connecticut
Brigham Young University, Utah
Brown University, Rhode Island
Bucknell University, Pennsylvania
California, University at Berkeley, California
California University at Los Angeles, California
Case Western Reserve University, Ohio
Catholic University of America, District of Columbia
Cincinnati University, Ohio
City University of New York, New York
City College, New York
Clemson University, South Carolina
Connecticut University of, Connecticut
Creighton University, Nebraska
Dayton, University of, Ohio
Delaware, University of, Delaware
Denver, University of, Colorado
De Paul University, Illinois
Detroit, University of, Michigan
Duke University, North Carolina
Duquesene University, Pennsylvania
East Tennessee State University, Tennessee
Eastern Michigan University, Michigan
Eastern New Mexico University, New Mexico
Fairleigh Dickinson University, New Jersey
Florida Agricultural and Mechanical University, Florida
Gonzaga University, Washington
Harvard University, Massachusetts
Idaho, University of, Idaho
Idaho State University, Idaho
Illinois Wesleyan University, Illinois
Indiana, University of, Pennsylvania
Iowa State University of Science & Technology, Iowa
Jacksonville University, Florida
John Hopkins University, Maryland
Kansas, University of, Kansas
Lehigh University, Florida
Long Island University, New York
Louisiana State University, Louisiana
Louisville, University of, Kentucky
Loyola University, Illinois
Loyola University of Los Angeles, California
Maine, University of, Maine
Marquette University, Wisconsin
Marshall University, West Virginia
Massachusetts, University of, Massachusetts
Michigan, University of, Michigan
Millikin University, Illinois
Mississippi, University of, Mississippi
Mississippi State University, Mississippi
Missouri, University of, Missouri
Montana, University of, Montana
Municipal University of Omaha, Nebraska
Nevada, University of, Nevada
New Hampshire, University of, New Hampshire
New York University, New York
Niagara University, New York
Loma Linda University, California
North Carolina at Chapel Hill, University of North Carolina
North Carolina State University at Raleigh, North Carolina
North Dakota, University of, North Dakota
North Texas State University, Texas

Northwestern University, Massachusetts
Northern Illinois University, Illinois
Northwestern University, Illinois
Notre Dame, University of, Indiana
Oklahoma City University, Oklahoma
Oklahoma State University, Oklahoma
Pacific Lutheran University, Washington
Pennsylvania, University of, Pennsylvania
Pennsylvania State University, Pennsylvania
Portland, University of, Oregon
Princeton University, New Jersey
Puget Sound, University of, Washington
Rice University, Texas
Roosevelt University, Illinois
Rutgers--The State University, New Jersey
St. Bonaventure University, New York
St. Louis University, Missouri
St. Mary's University, Texas
San Francisco, University of, California
Scranton, University of, Pennsylvania
Seattle University, Washington
South Dakota, University of, South Dakota
South Dakota State University, South Dakota
South Florida, University of, Florida
Southern California, University of, California
Southern Illinois University, Illinois
Southern Mississippi, University of, Mississippi
Southwestern Louisiana, University of, Louisiana
State University of New York, Albany, New York
State University of New York, Buffalo, New York
Stetson University, Florida
Syracuse University, New York.
Temple University, Pennsylvania
Texas, University of, Texas
Texas A & M University, Texas
Texas Southern University, Texas
Texas Women's University, Texas
Toledo, University of, Ohio
Tulane University, Louisiana
Tulsa, University of, Oklahoma
Union College and University, New York
United States International University, California
Utah, University of, Utah
Vanderbilt University, Tennessee
Virginia, University of, Virginia
Washburn University of Topeka, Kansas
Washington, University of, Washington
Washington and Lee University, Virginia
Washington State University, Washington
Washington University, Missouri
Wayne State University, Michigan
West Virginia University, West Virginia
Western Illinois University, Illinois
Western Michigan University, Michigan
Wichita State University, Kansas
Willamette University, Oregon
Wisconsin, University of, Wisconsin
Wittenberg University, Ohio
Xavier University, Ohio
Yale University, Connecticut
Youngstown State University, Ohio

LIBERAL ARTS COLLEGES

Alabama College, Alabama
Albany State College, Georgia
Amherst College, Massachusetts
Augustana College, South Dakota
Austin Peay State College, Tennessee
Baldwin-Wallace College, Ohio
Barnard College, New York
Bellarmine College, Kentucky
Bennett College, North Carolina
Bethel College, Tennessee
Brooklyn College, New York
Buena Vista College, Iowa
Cabrini College, Pennsylvania
California Baptist College, California
Carroll College, Wisconsin
Centenary College, Louisiana
Central Missouri State College, Missouri
Coe College, Iowa
Coker College, South Carolina
Colgate University, North Carolina
Columbia College, South Carolina
Concord College, West Virginia
Connecticut College, Connecticut
Converse College, South Carolina
Culver-Stockton College, Kentucky
Dana College, Nebraska
Davidson College, North Carolina
Doane College, Nebraska
East Texas Baptist College, Texas
Eastern Kentucky State College, Kentucky
Eastern Mennonite College, Virginia
Elizabethtown College, Pennsylvania
Emmanual College, Massachusetts
Hamline University, Minnesota
Hampton-Sydney College, Virginia
Hastings College, Nebraska
Holy Cross, College of the, Massachusetts
Holy Family College, Wisconsin
Hope College, Michigan
Howard Payne College, Texas
Illinois College, Illinois
Indiana Central College, Indiana
John Carroll University, Ohio
Judson College, Alabama
Kansas Weslyan University, Kansas
Kentucky State College, Kentucky
Lane College, Tennessee
Lincoln University, Missouri
Linfield College, Oregon
Loretta Heights College, Ohio
McPherson College, Kansas
Madison College, Virginia
Malone College, Ohio
Marietta College, Ohio
Marion College, Indiana
Massachusetts State College at Bridgewater, Massachusetts
Massachusetts State College at Westfield, Massachusetts
Merrimack College, Massachusetts
Monterey Institute of Foreign Studies, California
Mount Holyoke College, Massachusetts
Mount St. Joseph College, New York
Mount St. Mary's College, California
Mount St. Vincent's College, New York
Mount Union College, Ohio
Muhlenburg College, Pennsylvania
Munblein College, Illinois
Murray State College, Kentucky
Nazareth College, Michigan
North Central College, Illinois
Notre Dame, College of, California
Notre Dame College, Ohio
Notre Dame College, Staten Island, New York
Oglethorpe College, Georgia
Olivet Nazarene College, Illinois
Otterbein College, Ohio
Ozarks, College of the, Missouri
Pacific Union College, California
Peru State College, Nebraska
Plymouth State College, New Hampshire
Queens College, North Carolina
Sacramento State College, California
St. Benedict, College of, Minnesota

St. Joseph College, Maryland
St. Mary of the Woods College, Indiana
St. Mary's College, Indiana
St. Michael's College, Vermont
St. Olaf College, Minnesota
St. Procopius College, Illinois
Salem College, West Virginia
San Francisco College for Women, California
San Jose State College, California
Santa Fe, College of, New Mexico
Seton Hall College, Pennsylvania
Shaw University, North Carolina
Shorter College, Georgia
South Carolina State College, South Carolina
Southern Connecticut State College, Connecticut
Southern Missionary College, Tennessee
Southern State College, Arkansas
Southwestern State College, Oklahoma
Southwestern University, Tennessee
Springhill College, Alabama
Sweet Briar College, Virginia
Tarleton State College, Texas
Trinity College, District of Columbia
Troy State College, Alabama
Ursuline College, Kentucky
Valdosta State College, Georgia
Wabash College, Indiana
Walla Walla College, Washington
Wayne State College, Nebraska
Waynesburg College, Pennsylvania
Westchester State College, Pennsylvania
Western Kentucky State College, Kentucky
Western Maryland College, Maryland
Wheeling College, West Virginia
Wilberforce University, Ohio
William College, Massachusetts
Williamantre State College, Connecticut
Wisconsin State University at Eau Claire, Wisconsin
Wooster, College of, Ohio

JUNIOR COLLEGES

Alice Lloyd College, Kentucky
Andrew College, Georgia
Armstrong State College, Georgia
Bennett College, New York
Black Hawk College, Illinois
Bluefield College, Virginia
Bronx Community College, New York
Cameron State Agricultural College, Oklahoma
Centralia College, Washington
Chabot College, California
Cisco Junior College, Texas
City College of San Francisco, California
Clatsop Community College, Oregon
Concordia College, Oregon
Contra Costa College, California
Cumberland College of Tennessee, Tennessee
Daniel Payne College, Alabama
Desert, College of the, California
Donnelly College, Kansas
El Camino College, California
Georgia Military College, Georgia
Georgia Southwestern College, Georgia
Grossmont College, California
Hibbing Junior College, Minnesota
Holmes Junior College, Mississippi
Illinois Valley Community College, Illinois
Independence Community College, Kansas
Indian River Junior College, Florida
Jackson Community College, Michigan
Jamestown Community College, New York
Joliet Junior College, Illinois
Kendall College, Illinois
Lansing Community College, Michigan
Lee College, Tennessee
Lee College, Texas
Lincoln College, Illinois
Los Angeles Valley College, California
Maricopa County Junior College, Arizona
Mercy Junior College, Missouri
Meridian Junior College, Mississippi
Mesa Junior College, Colorado
Midway Junior College, Kentucky
Mississippi Delta Junior College, Mississippi
Modesto Junior College, California
Mohawk Valley Community College, New York
Monterey Peninsula College, California
Morristown College, Tennessee
Mount San Antonio College, California
Multnomah College, Oregon
Murray State A & M College, Oklahoma
Norman College, Georgia
Oklahoma Military Academy, Oklahoma
Orange County Community College, New York
Packer Collegiate Institute, New York
Palo Verde College, California
Pine Manor Junior College, Massachusetts
Reinhardt College, Georgia
St. John's River Junior College, Florida
San Diego Junior College, California
Santa Barbara City College, California
Santa Monica City College, California
Snead College, Alabama
South Georgia College, Georgia
Southeastern Christian College, Kentucky
Southeastern Iowa College, Iowa
Southwest Texas Junior College, Texas
Sue Bennett College, Kentucky
Sullins College, Virginia
Tyler Junior College, Texas
Solana Junior College, California
Valley Forge Military Junior College, Pennsylvania
Ventura College, California
Victor Valley College, California
Vicennes University, Indiana
Westbrook Junior College, Missouri

SPECIALIZED INSTITUTIONS

Agricultural and Technical College of North Carolina, North Carolina
Aquinas Institute of Philosophy and Theology, Illinois
California Institute of Technology, California
Cheyney State College, Pennsylvania
Chicago State College, Illinois
Concordia Teachers College, Illinois
East Stroudsburg State College, Pennsylvania
Fashion Institute of Technology, New York
Illinois Institute of Technology, Illinois
Illinois State University, Illinois
Mansfield State College, Pennsylvania
Massachusetts State College at Salem, Massachusetts
Montclair State College, New Jersey
Newark College of Engineering, New Jersey
New Haven College, Connecticut
Oregon College of Education, Oregon
Polytechnic Institute of Brooklyn, New York
Pratt Institute, New York
Rochester Institute of Technology, New York
Rose Polytechnic Institute, Indiana
Saint Charles College, Maryland
Slippery Rock State College, Pennsylvania
South Dakota School of Mines and Technology, South Dakota
Trenton State College, New Jersey
United States Military Academy, New York

APPENDIX D

LIST OF COLLEGES USED IN VALIDATING QUESTIONNAIRE

AND

RAW DATA ON QUESTIONNAIRE RESPONSES

LIST OF COLLEGES USED IN VALIDATING QUESTIONNAIRE

Agnes Scott College, Georgia
*Alliance College, Pennsylvania
*Alverno College, Wisconsin
Aquinas College, Michigan
*Anderson College, Indiana
Augustana College, Illinois
*Aurora College, Illinois
Barber-Scotia College, North Carolina
*Barry College, Florida
*Beaver College, Pennsylvania
*Belhaven College, Mississippi
*Beloit College, Wisconsin
*Bellarmine-Ursuline College, Kentucky
Bloomfield College, New Jersey
Bluffton College, Ohio
*Caldwell College for Women, New Jersey
California State College, Fullerton
*California State College, Hayward
*California State College, San Bernardino
Carson-Newman College, Tennessee
Carthage College, Illinois
Central Connecticut State College, Connecticut
College of Charleston, South Carolina
*Chatham College, Pennsylvania
*Chico State College, California
*Christian Brothers College, Tennessee
*Claremont Men's College, California
*Colby College, Maine
Concordia College, Minnesota
*Cumberland College, Kentucky
*Dallas, University of, Texas
*Dickinson College, Pennsylvania
*Dillard University, Louisiana
Dominican College, Wisconsin
Drury College, Missouri
*Duchesne College of the Sacred Heart, Nebraska
*Eastern Illinois University, Illinois
*Eastern Nazarene College, Massachusetts
*Eastern Washington State College, Washington
Emory and Henry College, Virginia
*Evansville College, Indiana (University of Evansville)
*Fairfield University, Connecticut
Fairleigh University, Connecticut
*Florence State College, Alabama
*Fontbonne College, Missouri
*Fort Hays State College, Kansas
Fort Lewis College, Ohio
Fort Wright College of the Holy Names, Washington
*Francis T. Nicholls State College, Louisiana
Franklin College of Indiana, Indiana
*Gallaudet College, District of Columbia
*Georgian Court College, New Jersey
*Goshen College, Indiana
Greensboro College, North Carolina
Hanover College, Indiana
*Hardin-Simmons University, Texas
*Harding College, Arkansas
*Hiram College, Ohio
*Hood College, Maryland
Humboldt State College, California
Hunter College, New York
*Huntington College, Indiana
*Idaho, College of, Idaho
*Kentucky Wesleyan College, Kentucky
La Salle College, Pennsylvania
Lander College, South Carolina
*Lewis and Clark College, Oregon
*Le Moyne College, Tennessee
Livingston College, North Carolina
Longwood College, Virginia
*Loras College, Iowa

*Manchester College, Indiana
*Manhattan College, New York
Marymount College, California
*Marymount College, Kansas
Maryville College, Tennessee
Massachusetts State College, Massachusetts
Mercyhurst College, Pennsylvania
*Middlebury College, Vermont
Mt. Angel College, Oregon
*Mount Marty College, South Dakota
Mount Mary College, Wisconsin
*Mount Mercy College, Iowa
*Nasson College, Maine
*Northwest Nazarene College, Idaho
*Norwich University, Vermont
*Notre Dame of Maryland College, Maryland
*Olivet College, Michigan
*Ouachita Baptist University, Arkansas
*Our Lady of the Lake College, Texas
*Pace College, New York
*Pfeiffer College, North Carolina
Pitzer College, California
Portland State College, Oregon
*Quincy College, Illinois
Radcliff College, Massachusetts
*Randolph-Macon Woman's College, Virginia
Reed College, Oregon
Regis College, Massachusetts
Ripon College, Wisconsin
Rocky Mount[illegible] College, Montana
*St. Ambrose [illegible]llege, Iowa
*St. Bernard College, Alabama
St. Edward University, Texas
*St. John Fisher College, New York
*St. John's University, Minnesota
*St. Martin's College, Washington
*St. Mary of the Plains College, Kansas
*St. Mary's College, Minnesota
St. Mary's University, Texas
St. Paul's College, Virginia
*St. Teresa, College of, Minnesota
St. Thomas, University of, Texas
*St. Vincent College, Pennsylvania
*Samford University, Alabama
*Seattle Pacific College, Washington
*San Fernando Valley State College, California
*Shimer College, Illinois
Simpson College, Iowa
*Southeastern State College, Oklahoma
*Southern California College, California
*Spelman College, Georgia
*Stanislaus State College, California
*State College at North Adams, Massachusetts
State College at Westfield, Massachusetts
*State University College, Buffalo, New York
*State University of New York, Binghamton
*Stephens College, Missouri
*Sterling College, Kansas
State University College at Geneseo, New York
Suffolk University, Massachusetts
*Tabor College, Kansas
Texas Wesleyan College, Texas
*The Citadel, South Carolina
*The College of St. Catherine, Minnesota
*Tougaloo College, Mississippi
Tusculum College, Tennessee
*Valley City State College, North Dakota
*Wake Forest State College, North Carolina
Warner Pacific College, Oregon
Wayne State College, Nebraska
Wells College, New York
West Texas State University, Texas
Westminister College, Utah
Wheaton College, Illinois
*Williams Woods, Missouri
*Wilmington College, Ohio
*Wisconsin State University, La Crosse, Wisconsin
*Wisconsin State University, Superior, Wisconsin
*Wofford College, South Carolina

*Colleges and Universities that responded. Percent response was 63 percent.

VALIDATION DATA

INFORMATION ON INTRODUCTORY COLLEGE CHEMISTRY COURSES

NUMBER OF COURSES OFFERED:

Number of Institutions	Total Number of Courses	One Course	Two Courses	Three Courses
94	120	74	20	2

Course Enrollment per year: 9354

Average Enrollment per course: $\frac{9354}{120} = 78$

Number of Different Course Titles: 28 (See attached pages for description)

COURSE PREREQUISITES:

Prerequisite	Number of Institutions	Percent
None	51	54
Test	1	1
Mathematics (3 years H.S. Math)	23	23
Math and Test	0	0
Other:		
H.S. Chemistry and Algebra	33	35
H.S. Grade	3	3
Natural Science	1	1
Chemistry	5	5

COURSE CREDIT:

	Credit in Semester Hours											
	1	2	3	4	5	6	8	9	10	12	Total Hours	Sem. Hrs/ Course
Number of Courses	1	1	1	2	5	6	78	1	24	1	960	7.2

INTRODUCTORY CHEMISTRY COURSE TITLES

Title	Number
1. Chemical Concepts	1
2. College Chemistry	2
3. Electro-Chemistry and Thermodynamics	1
4. Foundations of Physical Science	1
5. Fundamentals of Chemistry	3
6. General Chemistry	60
7. General College Chemistry	1
8. General Chemistry and Elementary Qualitative Analysis	1
9. General and Organic Chemistry	1
10. General Chemistry and Qualitative Analysis	3
11. General Inorganic Chemistry	6
12. General Inorganic and Qualitative Analysis	1
13. Inorganic Chemistry	3
14. Introductory Chemistry	9
15. Inorganic Qualitative Analysis	2
16. Kinetics and Chemical Equilibrium	1
17. Principles of Chemistry	8
18. Principles of Chemistry and Qualitative Analysis	1
19. Principles of Physics and Chemistry	1
20. Principles, Structure, and Bonding	3
21. Principles, Structure and the Physical Chemistry of Equilibrium Systems	1
22. Qualitative Analysis	3
23. Qualitative Inorganic Analytical Laboratory	1
24. Quantitative Analysis	2

INTRODUCTORY CHEMISTRY COURSE TITLES (Continued)

Title	Number
25. Solution Chemistry	1
26. Structural Chemistry	1
27. Theoretical Chemistry	1
28. Theoretical Inorganic Chemistry	1
Total No. of Courses	120

PREVIOUS HIGH SCHOOL CHEMISTRY EXPERIENCE

	Percent Experience and Number of Responses										
Academic Experience	0	1	2	3	4	5	6	7	8	9 or	Mean Percent
No Chemistry	10	6	5	1	0	20	1	0	0	49	13.2
Traditional Chem.	5	0	0	0	1	0	0	0	0	88	66.7
CBA or CHEMS	21	4	6	1	2	12	0	0	1	67	15.1

PERCENT OF STUDENTS WHO EVENTUALLY MAJOR IN CHEMISTRY

	Percent Experience										
	0	1	2	3	4	5	6	7	8	9 or	Mean Percent
Number of Responses	3	1	2	5	3	15	2	2	4	57	11.0

FACULTY PERSONNEL:

DEGREE OF PROFESSORS IN CHARGE OF COURSE

	Total Number	Degree				
		BS	MS	MS+	Ed.D.	Ph.D.
Number	94	1	19	0	0	74
Percent		1	20	0	0	79

NUMBER OF OTHER PROFESSORS AND DEGREES

	Total Number	Degree				
		BS	MS	MS+	Ed.D.	Ph.D.
Number	156	12	25	3	0	116
Percent		7.7	11.2	1.9	0	74.4

TOTAL NUMBER OF PROFESSORS AND THEIR DEGREES

	Total Number	Degree				
		BS	MS	MS+	Ph.D.	Ed.D.
Number	250	13	44	3	190	0
Percent		5.2	17.6	1.2	76.0	0

FIELD OF SPECIALIZATION OF PROFESSORS

Disciplines	Number	Percent
Chemistry	235	94.0
Education	4	1.6
Chemical Education	1	0.4
Science	1	0.4
Science Education	1	0.4
Home Economics	1	0.4
Biology	3	1.2
Physiology	1	0.4
Pharmacy	1	0.4
Physics	1	0.4
Chemical Engineering	1	0.4

PROFESSIONAL TRAINING AND RESPONSIBILITY OF STUDENT ASSISTANTS

Degree	Number of Assistants
None	145
BS	33
MS	00
Other (Not Designated)	32
Total	210

Average/College = $\frac{210}{94}$ = 2.2

Responsibility	Number of Colleges
Lecture	0
Laboratory and/or laboratory preparation	56
Other: Grading, recording, and/or bookkeeping	13
No assistants	15

ACCREDITED BY AMERICAN CHEMICAL SOCIETY (ACS)

	Yes		No	
	Number	Percent	Number	Percent
Number of Institutions	76	80	18	19

TYPICAL INTRODUCTORY CHEMISTRY COURSE OFFERED

Description	Responses	
	Number	Percent
a. No distinction as to chemistry background. All students take same course.	64	68
b. Course is designed in such a way that the better prepared student can complete the equivalent of a one year course in one semester.	4	4
c. Place all students together but compensate for the student who has had no prior study in chemistry by using some of the early laboratory periods as drill sessions to give students experience in nomenclature, elementary facts of atomic theory, and equation writing.	Extra 16 Regular 6	Extra 16 Regular 6
d. Selected students are given a brief review and then placed in an honors section by examination.	8	8
e. Offer several introductory chemistry courses of varying difficulty.	26	27
f. Give a sufficiently different course in the laboratory such that no student feels he is repeating the course. Try to eliminate trivia and introduce advanced and non-traditional topics.	23	24

REACTIONS TO STATEMENTS REGARDING THE UTILITY OF THE INTRODUCTORY CHEMISTRY COURSE

Statement	Responses					
	Agree		Disagree		Undecided	
	No.	%	No.	%	No.	%
The "conventional" course in college chemistry:						
1. is generally satisfactory for all students.	37	39	42	44	13	13
2. is more appropriate for students who major in chemistry than those who do not.	42	44	42	44	7	7
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics	57	60	18	19	15	15
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry.	15	15	48	51	24	25
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	54	57	12	12	21	22
6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to C.B.A. and CHEM study at the introductory college level.	20	21	38	40	29	30

DESCRIPTION OF LABORATORY MANUAL OR TEXTBOOK

Description	Response	
	Number	Percent
a. Only materials prepared by the chemistry staff.	7	7
b. Only published material which is available commercially.	25	26
c. A combination of the above.	59	62
d. Other		
1. Journal of Chemical Education or AC_3 experiments.	3	3

PRE-LABORATORY INSTRUCTION

Description	Response	
	Number	Percent
a. Students are expected to have read directions.	19	19
b. Students are assigned supplementary readings other than laboratory manual directions.	13	13
c. A pre-laboratory drill assures that students have read directions.	8	8
d. A pre-laboratory quiz assures that students have read directions.	0	0
e. A pre-laboratory quiz assures that students have read supplementary readings.	2	2
f. A pre-laboratory quiz assures that students have worked the drill.	14	14
g. The experiment is demonstrated.	80	85
h. Procedure is discussed.	77	81
i. The theoretical basis of the experiment is discussed.	75	79
j. Questions are answered.	75	79
k. Special emphases and different points are elucidated.	11	11
l. Other: Post lab quiz or discussion.	3	3

STUDENT METHOD OF HANDLING DATA

Description	Response: Number	Response: Percent
a. Data is recorded in duplicate by use of carbon paper.	10	10
b. Data is recorded on blank separate sheets.	8	8
c. Data is recorded in blank notebooks.	29	30
d. Data is recorded on special printed forms you provide separately.	19	20
e. Other: Data is recorded in laboratory manual.	28	29

TYPE OF LABORATORY REPORTING OF DATA

Description	Response: Number	Response: Percent
a. Fill in data and results on printed sheets.	53	56
b. Students design their own report sheets.	35	37
c. Full reports (essay form).	18	19
d. Sample calculations only.	28	29
e. Full calculations.	51	54
f. Duplicate raw data sheets (carbon paper record).	11	11
g. Supplementary questions are answered in the laboratory.	31	32
h. Graphs from data in the laboratory.	59	62
i. Other: (Form of data book)	13	13

SPECIAL PROJECTS

Number of Colleges	Percent Devoted to Projects			
	0	5	9 or	Mean Percent
4		X		
13			X	
77	X			
Total				17

CHALLENGES TO SUPERIOR STUDENTS

Description	Response	
	Number	Percent
A. No provisions made, because--		
1. No interest.	4	4
2. Lack of student time.	20	21
3. Lack of professor time.	27	28
4. Lack of facilities	17	18
5. Do not have, but are interested.	33	35
6. Other	17	18
B. Independent Study: (The student carries on a study of basic research under the direction of a faculty member and prepares a paper on his work in the manner of a journal article.) The nature of this independent study is a--		
1. Special laboratory project.	13	13
2. Special problem in qualitative analysis.	3	3
3. Special problem selected by the individual student.	9	9
4. Special problem selected by the chemistry department.	8	8
5. Do not have, but are interested.	21	22
6. No interest.	9	9
7. Other	10	10
C. Conference Study or Conference Sessions: (Informal meetings on a variety of topics-freshman presentation).		
1. Seminar	3	3

CHALLENGES TO SUPERIOR STUDENTS (Continued)

Description	Response	
	Number	Percent
2. Assist professors or graduate students in preparing papers to be presented at seminars.	1	1
3. Other		
(1) Advanced Placement	11	11
(2) Credit by Examination (ACS Exam.)	7	7
(3) Chemistry-Physics in one year by exam.	1	1

NEW COURSES

	Number of Responses	
	Yes	No
New course added in last two years.	19	75
Percent response to new courses.	20	79
Textbook change or revision and/or laboratory exercise changes or revision.	77	17
Percent response to revision.	81	18

DESCRIPTION OF COURSE REVISIONS

Statement	Response					
	No		Yes		Uncertain	
	No.	%	No.	%	No.	%
1. Have the content and program of instruction been considerably modified but the framework of the old course retained?	34	36	57	60	3	3

DESCRIPTION OF COURSE REVISIONS (Continued)

Statement	Response					
	No		Yes		Uncertain	
	No.	%	No.	%	No.	%
2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course?	44	46	50	53	0	0
3. Are you using an outline or syllabus which was prepared especially for the new course?	54	57	38	40	2	2
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc., as separate units?	46	48	41	43	7	7
5. Do you expect more reading outside the text in the new or revised course than in the old course?	64	68	29	30	1	1
6. Is the work in the new or revised course independent of collaboration with physicists?	29	30	62	65	3	3
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory?	89	94	3	3	2	2
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course?	81	86	13	13	0	0
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access?	53	56	37	39	4	4
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?	65	69	24	25	5	5

PROFESSOR OPINION AS TO WHAT THE INTRODUCTORY COURSE SHOULD BE

Description	Response	
	Number	Percent
Which of the following best represents your opinion of what the introductory course in college chemistry should be?		
1. A course in chemical principles with descriptive chemistry serving only to illustrate these concepts.	74	78
2. A course based heavily on laboratory and classroom demonstration of a phenomenon.	3	3
3. An integrated course in physics, chemistry, and mathematics.	6	6
4. An inventory of factual materials and phenomenological formulas needed for advanced study.	1	1
5. Other	7	7
a. Combination of above.		
b. A course emphasizing the experimental and observational basis of chemical theories and application of these theories to broad topics in descriptive chemistry.		
c. A course in chemical principles, relating and explaining descriptive chemistry.		
d. A course in chemical principles with laboratory, physics, mathematics, and application of principles; the goal, to teach the students to think creatively.		
e. Topical approach is more reasonable--but there are problems of texts and transferring this from one school to another. Our approach is toward the topical (bond and structure) but retaining moderate traditional organization.		

OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Description	Very Important		Some Importance		Not at all Important	
	No.	%	No.	%	No.	%
1. Show the relationship of chemistry to other sciences.	46	48	44	46	2	2
2. Help the student to understand the nature of matter and its transformations.	82	87	10	10	0	0
3. Develop the ability to do critical thinking.	85	90	8	8	0	0
4. Make students familiar with the facts, principles, and concepts of chemistry.	82	87	9	9	0	0
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	29	30	57	60	6	6
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	34	36	48	51	10	10
7. Give students an idea of the importance and significance of chemistry in our national life.	18	19	60	63	14	14
8. Development of specific interests, habits, and abilities which should be contributed to by <u>all courses</u> in science.	47	50	41	43	5	5
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	7	7	39	41	45	47
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	67	71	25	26	0	0
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	24	25	58	61	9	9
12. Teach students to be precise in observations and expression.	81	86	12	12	0	0

OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE (Continued)

Description	Very Important		Some Importance		Not at all Important	
	No.	%	No.	%	No.	%
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	63	67	27	28	1	1
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	69	73	22	23	0	0
15. Formulate, as well as answer, questions.	60	63	31	32	1	1
16. Develop intellectual honesty rather than foster the search for the "right" answers.	78	82	9	9	4	4
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	51	54	40	42	1	1
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	51	54	38	40	2	2
19. Provide the student direct experiences related to concepts expounded in the classroom.	49	52	41	43	1	1
20. Demonstrate the extension of human sensory perception by appropriate instruments.	20	21	49	52	21	22
21. Develop selected manipulatory skills involved in laboratory techniques.	42	44	47	50	4	4
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the						

OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE (Continued)

Description	Very Important		Some Importance		Not at all Important	
	No.	%	No.	%	No.	%
existence of laboratories and the basis of action carried out by those who work there.	45	47	41	43	6	6
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	43	45	44	46	6	6
24. Other	2	2	0	0	0	0
a. To read for content.						
b. Use common sense.						

MOST IMPORTANT OBJECTIVES

Objective	Choice					
	1	2	3	4	5	Total
1	1	1	6	2	4	14
2	23	11	4	6	2	46
3	30	11	12	4	2	59
4	12	19	11	2	2	46
5	0	0	1	2	1	4
6	0	2	1	2	4	9
7	1	0	3	1	2	7
8	4	14	1	2	2	23
9	0	0	0	0	0	0
10	2	8	7	10	6	33
11	0	0	0	0	2	2
12	1	7	13	11	7	39
13	3	2	7	2	6	20
14	0	1	6	5	4	16
15	1	2	1	5	6	15

MOST IMPORTANT OBJECTIVES (Continued)

Objective	Choice 1	2	3	4	5	Total
16	3	5	3	8	10	29
17	0	1	2	5	2	10
18	0	0	1	1	4	6
19	0	0	3	4	4	11
20	0	0	1	1	1	3
21	0	0	0	3	6	9
22	1	0	0	3	1	5
23	1	1	0	3	3	8
24	1	0	0	0	0	1

Order of Most Important Objectives: 3 2 4 12 10 16

EVALUATION OF INTRODUCTORY CHEMISTRY COURSE

Method	Number of Responses: Number Spasmodic	Periodic	Total	Percent
1. Special examination.	0	33*	33	36.0
2. Subjective observations.	27	7	34	36.0
3. Student-completed questionnaires.	3	14	17	18.0
4. Discussion (faculty).	14	24	38	41.0
5. No evaluation.	0	0	0	0.0
6. Other:				
a. Student feedback.	0	1	1	1.1
b. Comparison with prior years.	0	1	1	1.1
c. Success in upper division.	0	3	3	3.2

*Most use ACS Exam.

SUPPLEMENTARY MATERIALS, EQUIPMENT, AND METHODOLOGY USED IN THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Supplementary Materials	In Classroom		Outside Class	
	No.	%	No.	%
1. Study guides prepared by the chemistry faculty.	16	17	9	9
2. Student personal data inventories.	16	17	3	3
3. File of previous given chemistry tests.	17	18	23	24
4. Bibliography of reading materials for students.	5	5	24	25
5. Study Materials:				
a. Articles.	13	13	23	24
b. Books.	13	13	39	41
c. Film Loops.	13	13	6	6
d. Programmed Materials.	4	4	29	30
e. Other	2	2	0	0
6. Atomic and molecular models.	66	70	3	3
7. Visual Aids:				
a. Filmstrips.	35	37	3	3
b. Overhead projector.	58	61	2	2
c. Opaque projector.	17	18	1	1
d. 8 mm or 16 mm projector.	43	45	0	0
e. Closed circuit television.	1	0	0	0
f. Other (Specify).	2	2	0	0
8. Paperback books available in the college bookstore.	7	7	55	58
9. Videotape.	0	0	1	1
10. Computer assisted instruction.	2	2	1	1
11. Other	0	0	1	1

Equipment Use

Equipment	Demonstration		Student Experiments		Study of Design	
	No.	%	No.	%	No.	%
12. Direct reading balances.	9	9	52	55	0	0
13. Gas Chromatograph.	19	20	5	5	0	0
14. Infra-red spectrophotometer.	22	23	3	3	1	1

SUPPLEMENTARY MATERIALS, EQUIPMENT, AND METHODOLOGY USED IN THE INTRODUCTORY COLLEGE CHEMISTRY COURSE (Continued)

Equipment	Equipment Use					
	Demonstration		Student Experiments		Study of Design	
	No.	%	No.	%	No.	%
15. Bausch and Lomb Spectronic 20.	12	12	26	27	2	2
16. pH Meter.	17	18	37	39	0	0
17. Conductivity bridge.	5	5	9	9	1	1
18. Polarimeter.	8	8	7	7	0	0
19. Geiger counter or scintillator.	16	17	20	21	0	0
20. Paperchromatography.	9	9	16	17	0	0
21. Other:						
a. Electrodeposition.	1	1	0	0	0	0
b. Thin layer chromatography.	1	1	0	0	0	0
c. Ultra Violet.	1	1	0	0	0	0
d. Mass spectrum.	1	1	0	0	0	0
e. Isotensioscope.	1	1	0	0	0	0
f. Column chromatography.	1	1	0	0	0	0

Outside Materials	Number	Percent
22. Field trips, exploration trips, local industry, resource speakers (outside speakers).	4	4
23. Chemistry club and parties.	43	45
24. Other	0	0

Methodology and Techniques	Number	Percent
25. Demonstrations (teacher and/or students).	67	71
26. Panel Discussions.	4	4
27. Team teaching and/or committee teaching.	10	10
28. Programmed instruction.	23	24
29. Review sessions and/or tutorial sessions.	67	71
30. Conference quizzes.	9	9
31. Series of quizzes, tests - objective and subjective.	76	80

SUPPLEMENTARY MATERIALS, EQUIPMENT, AND METHODOLOGY USED IN THE INTRODUCTORY COLLEGE CHEMISTRY COURSE (Continued)

Methodology and Techniques	Number	Percent
32. Student conferences with faculty members.	61	64
33. Regular problem assignments.	83	88
34. Urge the students in class and out of class to use the library for other than textbook reading.	60	63
35. Require term papers on topics not adequately covered in textbooks or secondary sources.	16	17
36. Special topics and reports.	6	6
37. Student presentation of problems and solutions.	14	14
38. Assign research journal articles for reading.	15	15
39. Presenting the limited but useful aspects of "black box" instruments.	8	8
40. Let students plan, execute, and interpret experiments.	15	15
41. Using "open-ended" experiments.	15	15
42. Devise experiments so that original sources must be consulted.	25	26
43. Using some laboratory experiments which "stand on their own feet", i.e., experiments which are not dependent on materials discussed in the classroom.	5	5
44. Using simple "mock-up" rather than complex apparatus to concentrate the student's attention on ideas rather than manipulation.	45	47
45. Other: Student committees on special topics such as Nuclear Chemistry, etc.	1	1

FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE

Statement	Number	Percent
1. Topics are unrelated to student interest.	41	43
2. Too much theory.	30	31
3. Not enough laboratory work.	9	9
4. Insufficient or inadequate laboratory equipment.	25	26
5. Lack of library facilities.	4	4
6. Not enough individual work.	26	27
7. Too much memory work.	29	30
8. Subject too formally presented.	17	18
9. Instructor teaching too many subjects or students.	20	21

FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE (Continued)

Statement	Number	Percent
10. Facts taught as ends (products) of science rather than a means (processes) of science.	23	24
11. Too much teacher dependence on textbook.	16	17
12. Too much telling - too much teacher domination.	23	24
13. Failure of instructor to clarify a general principle.	17	18
14. Failure to use "practical tangibles" in place of "textbook tangibles."	20	21
15. Too little faculty time - too involved in research or other activities.	22	23
16. Poor instruction by graduate assistants.	8	8
17. Other:	11	11
a. Lack of teacher enthusiasm; failure to show importance in modern America.		
b. Too demanding: lowers grade point average.		
c. Students with poor study habits fall behind and despair.		
d. There is a wide gap between the analytical approach in college (and dull teachers or just call them "uncommitted") and descriptive presentation in high school.		
e. Weakness of effort on student's part (afraid of failing).		
f. Course size - professors could not give as much personal attention to students as they presently get.		
g. Laboratory work that is "mickey mouse" (two responses).		
h. Poor teaching: (1) lack of love for subject. (2) lack of love for students.		
i. Too many too poor students.		

ADDITIONAL COMMENTS BY THE RESPONDENTS:

"Just a few thoughts: (1) The teachers (in college) are trained to do research. Are they also trained to teach? (2) As to teaching versus research, a more pertinent comparison could be: creative (teaching or research) versus routine (teaching or research). This could involve everyone from writers to cafeteria staff. (3) Those who treat the bodies of young people (the medical doctors) and those who represent, protect and manage their legal rights (lawyers) have to have a graduate degree and further examination. Those who manipulate their minds in colleges need only a graduate degree. It is just my suggestion to require additional examinations, but the lack of criteria in establishing and evaluating the teachers competence and performance cannot make the survey of college teaching as complete as it would be desirable."

"Above all, we need college chemistry teachers whose first interest is teaching. Research interests too frequently dominate faculty interest, ingenuity, and time."

"There is a need to revise our whole chemistry curriculum—e.g., how much and what year qualitative and quantitative analysis, how much instrumental analysis; instruments change, become more sophisticated—is it necessary to teach their use in undergraduate chemistry?"

"I would favor equipment that is simple enough so that the technical construction would not detract the students from the principles of operation. The further development of inexpensive, simple modular equipment by manufacturers would be appreciated."

REASONS FOR CHANGING THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Statements	Number	Percent
a. The availability of more equipment and more modern equipment for laboratory and instructional use.	54	57
b. Impact of CBA, CHEMS, PSSC courses.	42	44
c. The number of chemistry majors is diminishing.	23	24
d. Theories of chemistry are constantly developing.	43	45
e. Advent of general chemistry textbooks with a change in emphasis.	38	40
f. Flood of new information appearing in the chemical literature.	19	20
g. Large number of students beginning the study of introductory college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and/or mathematics.	50	52
h. Other	2	2
1. Preparation of entering freshmen.		
2. Students need a change of pace; CBA, CHEMS have skimmed off the cream of the crop.		

ITEMS THAT SHOULD BE DEVELOPED TO IMPROVE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Statements	Very Important		Some Importance		Not at all Important	
	No.	%	No.	%	No.	%
A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests.	30	31	39	41	20	21
B. The preparation of tests designed to measure the achievement of students with respect						

ITEMS THAT SHOULD BE DEVELOPED TO IMPROVE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY (Continued)

Statements	Very Important		Some Importance		Not at All Important	
	No.	%	No.	%	No.	%
to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as the content and the ability to do critical thinking.	52	55	30	31	4	4
C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching.	31	32	39	41	17	18
D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching techniques) and in the methods of educating college teachers of chemistry.	47	50	32	34	11	11
E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten.	70	74	14	14	6	6
F. Other						
(1) Change high school courses so that they teach a few areas well, i.e., atomic structure, gas laws, acid base theory, and leave all else to college courses.	1	1	0	0	0	0

APPENDIX E

RAW DATA ON T-TEST SCORES

RAW DATA ON T-TEST SCORES

Table and Statement		Mean Univ.	Mean L.A.	Mean J.C.	Mean Spec.	Standard Deviation Univ.	Standard Deviation L.A.	Standard Deviation J.C.	Standard Deviation Spec.
15-A	a	.512	.636	.683	.583	.503	.484	.471	.515
	b	.134	.909	.732	.167	.343	.289	.264	.389
	c	.732	.364	.341	.833	.306	.667	.656	.289
	d	.854	.909	.000	.000	.281	.289	.000	.000
	e	.115	.584	.609	.100	.144	.978	.997	.113
	f	.268	.442	.171	.833	.446	.500	.381	.289
16-A	1	1.683	1.689	1.390	1.833	.701	.831	.666	.669
	2	1.451	1.403	1.366	1.500	.669	.712	.698	.718
	3	1.890	1.974	1.927	2.083	.832	.903	.906	.798
	4	1.695	1.584	1.586	1.667	.101	.978	.948	.793
	5	1.720	1.689	1.659	2.333	.920	.977	.965	.985
	6	2.390	2.404	2.805	2.333	.885	.799	.601	.651
20-A	1	.646	.753	.603	.833	.596	.566	.521	.937
	2	.646	.623	.609	.500	.506	.539	.542	.522
	3	.524	.571	.366	.667	.549	.524	.488	.651
	4	.659	.610	.659	.417	.652	.610	.530	.515
	5	.305	.403	.585	.333	.602	.591	.631	.651
	6	.756	.688	.634	.333	.432	.494	.623	.492
	7	.854	.779	.746	.767	.322	.315	.358	.389
	8	.183	.247	.365	.230	.447	.467	.381	.452
	9	.402	.532	.610	.583	.563	.598	.542	.515
	10	.415	.364	.512	.333	.647	.536	.675	.492
21-A	a	.890	.935	.927	.917	.314	.248	.263	.289
	b	.110	.420	.220	.250	.314	.352	.419	.452
	c	.195	.116	.171	.167	.398	.323	.381	.389
	d	.195	.169	.121	.250	.398	.377	.331	.452
	e	.012	.013	.000	.000	.110	.114	.000	.000
	f	.012	.026	.487	.000	.110	.160	.218	.000
	g	.049	.091	.220	.000	.216	.289	.419	.000
	h	.780	.922	.780	.916	.416	.269	.419	.289
	i	.695	.831	.780	.833	.463	.377	.419	.389
	j	.720	.831	.780	.833	.452	.377	.419	.389
	k	.671	.714	.707	.750	.473	.455	.461	.452
	l	.098	.909	.220	.833	.296	.299	.690	.289
23-A	a	.671	.345	.585	.917	.315	.501	.264	.289
	b	.268	.338	.244	.250	.315	.4[illegible]	.419	.453
	c	.121	.143	.293	.166	.399	.352	.381	.389
	d	.232	.364	.244	.250	.399	.484	.331	.452
	e	.524	.481	.537	.000	.110	.503	.000	.000
	f	.085	.039	.073	.000	.110	.194	.208	.000

RAW DATA ON T-TEST SCORES

Table and Statement		Mean				Standard Deviation			
		Univ.	L.A.	J.C.	Spec.	Univ.	L.A.	J.C.	Spec.
23-A	g	.378	.494	.341	.000	.217	.303	.419	.000
	h	.585	.636	.683	.917	.416	.484	.419	.289
	i	.146	.129	.146	.083	.463	.338	.419	.389
26-A	1	.646	.753	1.341	.833	.595	.566	.521	.937
	2	.646	.623	1.073	.500	.549	.524	.488	.651
	3	.524	.571	1.024	.667	.549	.524	.488	.515
	4	.659	.610	1.073	.416	.652	.610	.529	.515
	5	.305	.403	1.586	.333	.002	.590	.631	.651
	6	.756	.688	1.707	.333	.432	.494	.623	.492
	7	.085	.078	1.561	.167	.322	.315	.358	.389
	8	.183	.247	1.488	.250	.448	.463	.581	.452
	9	.402	.532	2.073	.583	.563	.598	.542	.515
	10	.415	.364	1.073	.333	.647	.536	.675	.492
	11	1.829	2.091	1.463	1.833	1.570	1.624	1.112	1.586
	12	1.476	1.545	1.073	1.250	.593	.619	.480	.452
	13	1.037	1.078	1.219	1.000	.292	.315	.264	.000
	14	1.073	1.052	1.146	1.000	.344	.223	.156	.000
	15	1.085	1.078	1.390	1.333	.358	.270	.264	.493
	16	1.671	1.727	1.121	1.833	.568	.504	.547	.577
	17	1.732	1.767	1.363	2.000	.668	.626	.642	.738
	18	1.866	1.857	1.244	1.833	.643	.601	.634	.718
	19	1.439	1.597	1.414	1.333	.611	.748	.553	.492
	20	2.354	2.402	1.634	2.417	.674	.391	.519	.669
	21	1.170	1.182	1.341	1.250	.466	.388	.345	.452
	22	1.732	1.766	1.414	1.583	.629	.535	.595	.515
	23	1.109	1.091	1.313	1.000	.416	.289	.264	.000
	24	1.341	1.286	.000	1.083	.526	.535	.419	.289
35-A	1	.024	.753	.854	.833	.155	.566	.358	.389
	2	.366	.623	.024	.000	.484	.539	.156	.000
	3	.305	.571	.073	.250	.463	.524	.263	.452
	4	.280	.610	.220	.083	.452	.610	.419	.288
	5	.195	.402	.756	.750	.398	.591	.434	.452
	6	.232	.688	.171	.000	.425	.494	.380	.000
	7	.110	.078	.902	.833	.315	.315	.300	.389
	8	.280	.247	.756	.750	.452	.463	.434	.452
	9	.158	.532	.975	.833	.367	.598	.156	.389
	10	.122	.364	.707	.667	.329	.162	.460	.492
	11	.159	.209	.146	.083	.367	.619	.357	.289
	12	.268	.155	.220	.083	.446	.315	.419	.289
	13	.256	.108	.220	.250	.439	.223	.419	.452
	14	.512	.105	.098	.000	.503	.270	.300	.000
	15	.354	.108	.073	.167	.481	.504	.264	.389

RAW DATA ON T-TEST SCORES

Table and Statement		Mean				Standard Deviation			
		Univ.	L.A.	J.C.	Spec.	Univ.	L.A.	J.C.	Spec.
35-A	16	.231	.173	.146	.250	.424	.626	.357	.452
	17	.500	.177	.219	.333	.503	.601	.419	.492
	18	.378	.186	.171	.083	.488	.748	.380	.289
	19	.256	.160	.561	.583	.439	.590	.502	.515
	20	.439	.240	.268	.083	.499	.388	.449	.289
	21	.122	.118	.000	.000	.329	.535	.000	.000
38-A	a	.512	.207	.756	.416	.503	.408	.111	.514
	b	.354	.545	.244	.167	.481	.501	.434	.389
	c	.232	.429	.292	.083	.425	.498	.460	.289
	d	.500	.234	.512	.583	.503	.426	.506	.515
	e	.378	.623	.512	.417	.488	.488	.506	.515
	f	.256	.532	.317	.167	.439	.502	.471	.389
	g	.439	.260	.439	.250	.499	.441	.502	.452
39-A	1	.537	.532	.363	.667	.502	.502	.488	.492
	2	.366	.312	.414	.333	.404	.406	.499	.492
	3	.048	.130	.244	.167	.217	.338	.435	.389
	4	.317	.273	.293	.250	.468	.448	.461	.452
	5	.243	.065	.146	.083	.155	.248	.357	.289
	6	.365	.286	.341	.083	.485	.454	.480	.289
	7	.304	.376	.366	.417	.463	.488	.488	.515
	8	.280	.246	.293	.417	.452	.434	.460	.515
	9	.195	.338	.244	.333	.398	.476	.434	.492
	10	.232	.220	.220	.230	.425	.417	.419	.452
	11	.110	.208	.293	.333	.315	.408	.461	.492
	12	.280	.312	.439	.250	.452	.466	.302	.452
	13	.158	.221	.146	.250	.367	.417	.358	.452
	14	.122	.234	.195	.333	.329	.426	.401	.492
	15	.158	.130	.220	.333	.367	.338	.419	.492
	16	.268	.649	.122	.250	.445	.248	.331	.452
	17	.256	.208	.293	.333	.439	.408	.401	.289
41-A	A	1.926	1.779	1.951	1.583	.979	.926	.740	.900
	B	1.537	1.364	1.220	1.333	.878	.793	.725	.778
	C	1.671	1.480	1.195	1.167	.917	.771	.679	.718
	D	1.488	1.338	1.439	1.333	.850	.699	.776	.651
	E	1.268	1.312	1.170	1.417	.817	.748	.667	.900

APPENDIX F

TEXTBOOKS AND SYSTEMS APPROACH

TEXTBOOKS AND SYSTEMS APPROACH

The interested reader is referred to an article entitled "Chemical Publishers Push Teaching Aids" for a review of the best-selling general chemistry textbooks and a discussion of the systems of "package" approach to teaching freshman chemistry. The systems approach is designed to fill a need of the sorely pressed and harried teacher of general chemistry who needs teaching aids to supplement the textbook. Some of the best-selling general chemistry textbooks were listed as follows:*

Author(s)	Publisher
M. A. Sienko and R. A. Plane	McGraw Hill (two textbooks)
C. E. Mortimer	Reinhold
H. P. Gray and G. P. Haight	W. A. Benjamin
C. H. Sorum	Prentice-Hall
R. Johnson and E. Grunwald	Prentice-Hall
C. W. Keenman and J. H. Wood	Harper and Row
J. Quagliano	Prentice-Hall

Dissatisfaction with the laboratory in freshman chemistry as shown by an unpublished survey by Harper and Row in 1967 spurred them to develop series of laboratory "separates." This series will consist of separate laboratory experiments in general chemistry, each written and tested by college and university chemistry professors.#

*Not listed according to sale.

#"Chemical Publishers Push Teaching Aids," Chemical and Engineering News, 46, August 19, 1968, pp. 32-35.

APPENDIX G

RAW DATA

TABLE A. RAW DATA ON THE NUMBER OF TEACHER RESPONSES TO QUESTIONS RELATING TO COURSE AND TEXTBOOK CHANGES

Types of Changes	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y[a]	N[b]	U[c]	Y	N	U	Y	N	U	Y	N	U	Y	N	U
1. Have the content and program of instruction been considerably modified but the framework of the old course retained?	46	33	3	51	23	3	26	14	1	5	5	2	128	75	9
2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course?	51	30	1	44	31	2	23	17	1	6	6	0	124	84	4
3. Are you using an outline or syllabus which was prepared especially for the new course?	39	41	2	42	34	1	15	26	0	6	5	1	102	106	4
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units?	38	36	8	37	35	5	25	15	1	5	7	0	105	93	14
5. Do you expect more reading outside the text in the new or revised course than in the old course?	16	62	4	23	50	4	18	20	3	2	9	1	59	141	12
6. Is the work in the new or revised course independent of collaboration with physicists?	62	20	0	51	25	1	20	18	3	4	8	0	137	71	4

TABLE 4. (Continued)

Types of Changes	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y	N	U	Y	N	U	Y	N	U	Y	N	U	Y	N	U
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory?	5	76	1	4	72	1	6	35	0	2	10	0	17	193	2
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course?	11	69	2	17	59	1	11	28	2	3	9	0	42	165	5
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access?	27	52	3	33	40	4	23	17	1	7	5	0	90	114	8
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?	23	54	5	24	51	2	13	24	4	4	8	0	64	137	11

[a]Y - Yes

[b]N - No

[c]U - Uncertain

TABLE B. RAW DATA ON THE NUMBER OF TEACHER REACTIONS TO STATEMENTS CONCERNING THE CONVENTIONAL COURSE IN COLLEGE CHEMISTRY

The "conventional course in college chemistry:	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	D[b]	U[c]	A	D	U	A	D	U	A	D	U	A	D	U
1. is generally satisfactory for all students.	22	48	8	31	31	12	12	20	8	6	5	1	71	104	29
2. is more appropriate for students who major in chemistry than those who do not.	31	40	9	30	29	14	23	14	2	4	6	2	88	89	27
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	44	30	5	44	23	6	28	8	4	8	2	2	124	63	17
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry.	15	43	18	11	36	23	9	17	12	3	5	4	38	101	57
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	34	15	25	41	9	21	24	4	11	5	3	3	104	31	60
6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to CBA and CHEM study at the introductory college level.	28	28	19	22	27	18	13	14	9	1	6	5	64	75	51

[a] A - Agree   [b] D - Disagree   [c] U - Uncertain

APPENDIX H

COMPUTER PROGRAM

```
// JOB
// FOR                          DODSON
*IOCS(1132 PRINTER, CARD,DISK,TYPEWRITER,KEYBOARD)
*ONE WORD INTEGERS
** BROWN DODSON PROGRAM STD,MEAN, CORR MATRIC
      DEFINE FILE 1(240,320,U,NX)
      DIMENSION XIMP(160),LCT(10), TEMP(10,8),L(8),DAT(212,8)
     1,X(212,8), C(8,8),SX(8),STD(8)
      EQUIVALENCE (DAT(212,8),X(212,8))
      M=8
C CHANGE NYZ TO EQUAL THE NO OF VARR. YOU HAVE
C  FORMAT 2 MUST FIT YOUR DATA
      NX=1
      NXX=1
      NZZ=1
      NYZ=116
3     READ(2,2)(XIMP(IZ),IZ=1,NYZ)
2     FORMAT(3X,F1.0,F4.0,F1.0,5F2.0,4X,F1.0,5F2.0,41F1.0/3X,F2.0,29F1.0
     1,3X,24F1.0,5F2.0,F1.0,F1.0///)
      WRITE(1'NX)XIMP
      CALL LCARD(LA)
      GO TO (3,4),LA
4     N=NX-1
      XN=N
5     WRITE(1,7)N
7     FORMAT(I2,'CARDS HAVE BEEN READ'//'TYPE THE 8 VAR. NO YOU WANT COR
     1R.(I3) ')
      CALL DATSW(7,ND)
      GO TO (500,601),ND
601   READ(6,8)(L(MM),MM=1,8)
8     FORMAT(I3)
600   DO 9 JX=1,N
      READ(1'JX)XIMP
      DO 109J=1,M
      LA=L(J)
      X(JX,J)=XIMP(LA)
109   DAT(JX,J)=XIMP(LA)
9     CONTINUE
      CALL DATSW (4,ND)
      GO TO (878,877),ND
877   WRITE(3,60) L
60    FORMAT(1H0,1X,'VARR', 8I13)
878   GO TO 100
1001  CALL DATSW (6,ND)
      GO TO (300,301),ND
300   WRITE(3,61) L
61    FORMAT(1H0,40X,'FREQUENCY DISTRIBUTION'//1X,'VARR',8I13).
      DO 42 K=1,M
      DO 40 J=1,10
40    LCT(J)=0
      DO 41 J=1,N
      IP=DAT(J,K)+1.5
      IF(IP-10)41,400,400
400   IP=10
41    LCT(IP)=LCT(IP)+1
      DO 62 J=1,10
62    TEMP(J,K) =LCT(J)
42    CONTINUE
      DO 63 J=1,10
```

```
      JJ=J-1
      WRITE(3,65) JJ, (TEMP(J,K), K=1,8)
65    FORMAT(1H0,1X, I4,8F13.0)
      DO 64 KK=1,M
64    TEMP(J,KK)=TEMP(J,KK) / XN
63    WRITE(3,66)(TEMP(J,NN),NN=1,8)
66    FORMAT(1H ,1X,'PERCENT',1X,8F13.2)
301   CALL DATSW (7,ND)
      GO TO (500,302),ND
500   IF(NXX-NYZ)513,5,5
513   NXZ= NXX
      INDX=2
      NZZ=NZZ+(M-1)
      IF (NZZ-NYZ) 511,511,510
510   L(1)=NXZ
      NXX=NXZ+1
      NCONT=NZZ-(M-2)
      DO 502  II=NCONT,NYZ
      L(INDX)=II
502   INDX=INDX+1
      NZZ=NXX
      IF(NZZ-NYZ)600,302,302
511   L(1)=NXZ
      NCONT=NZZ-(M-2)
      DO 512  II=NCONT,NZZ
      L(INDX)=II
512   INDX=INDX+1
      GO TO 600
302   CALL DATSW (8,ICK)
      GO TO (29,600),ICK
29    CALL EXIT
100   CALL DATSW(1,ND)
      GO TO (14,16),ND
14    WRITE(1,15)
15    FORMAT('DATSW 1 CYCLES'/6X,'2 SUMX'/6X, '3 STD'/              6X,'4 C
     1ORR MATRIC'/6X,'5 MEANS'/6X'6 SUMX**2 AND SUM X*Y'/ 6X,'7 AUTOMATI
     3C'/6X,'8 ON AND 7 OFF WILL TERMINATE THE PROGRAM'/6X,'9 WILL TAKE
     4 THE PROGRAM OUT OF AUTOMATIC'/ 6X, 'SET DATSWS AND PUSH START')
      PAUSE 2222
16    MM=0
      XN=N
      DO 1  IT=1,M
      SX(IT)=0.0
      DO 1  J=1,N
1     SX(IT)=SX(IT)+X(J,IT)
      DO 51IT=1,M
      LIT=IT
      DO 51J=LIT,M
      C(IT,J)=0.0
      DO 51K=1,N
51    C(IT,J)=C(IT,J)+X(K,IT)*X(K,J)
      DO 6  IF=1,M
      FACI= XN*C(IF,IF)-SX(IF)**2
      IP=IF+1
      DO 6  J=IP,M
6     C(IF,J)=(XN*C(IF,J)-SX(IF)*SX(J))/SQRT((XN*C(J,J)-SX(J)**2)*FACI)
      CALL DATSW(2,ND)
      GO TO (69,68),ND
```

```
69      MM=MM+1
        WRITE(3,10) SX
10      FORMAT(1H0, 1X,'SUMX',2X, 8(E13.7, 1X))
68      CALL DATSW(3,ND)
        GO TO (81,85),ND
81      DO 91K=1,M
91      STD(K)=SQRT((C(K,K)/XN)-(SX(K)/XN)**2)
        WRITE(3,101)  STD
101     FORMAT(1H 1X,'STD       ',8F13.3)
85      CALL DATSW (5,ND)
        GO TO (90,82),ND
90      MM=MM+1
        WRITE(3,93)(C(J,J), J=1,M)
93      FORMAT(1H ,1X,'SUMSQ',1X,8(E13.7,1X))
82      CALL DATSW (4,ND)
        GO TO (70,71),ND
70      MM=MM+1
        WRITE(3,22)L
22      FORMAT(1H0,15X,'I N T E R C O R R   M A T R I C',//8X,8(2X,I11))
        DO 701IAP=1,M
701     C(IAP,IAP)=1.0
        NZ=0
        CALL DATSW(7,ND)
        GO TO (821,819),ND
821     WRITE(3,822)(C(1,J),J=1,M)
822     FORMAT(1H0,14X,8(E10.3,3X))
        GO TO  71
819     DO 811 IXT=1,M
        NZ=NZ+1
25      FORMAT(1H0,1X,I4,9X,8(F10.5,3X))
811     WRITE(3,25)L(NZ),  (C(J,IXT),J=1, NZ)
71      CALL DATSW(5,ND)
        GO TO (72,73),ND
72      MM=MM+1
        DO 74 I=1,M
74      STD(I)=SX(I)/XN
        WRITE(3,75) STD
75      FORMAT(1H0,1X,'MEANS',2X,8F13.3)
73      IF (MM)77,77,79
77      WRITE(1,78)
78      FORMAT('TURN ON DATA SWITCH 1 AND PUSH START')
        PAUSE 3333
        CALL DATSW (9,NOVER)
        GO TO (999,5),NOVER
999     CALL DATSW (1,ND)
        GO TO (350,79),ND
350     GO TO 100
79      GO TO 1001
        END
// XEQ
```

```
// JOB
// FOR
*IOCS(1132 PRINTER, CARD, TYPEWRITER , KEYBOARD)
*ONE WORD INTEGERS
**        DODSON T SCORES
      DIMENSION            XTOT(500), YTOT(500), STDA(500),STDB(500)
     1,X(500)
1000  NVAR=207
      XNA=0.0
      XNB=0.0
      DO 1 J=1,NVAR
      XTOT(J)=0.0
      YTOT(J)=0.0
      STDA(J)=0.0
1     STDB(J)=0.0
10    READ(2,2)(X(K),K=1,NVAR)
2     FORMAT(3X,F1.0,F4.0,F1.0,5F2.0,4X,F1.0,5F2.0,41F1.0/3X,F2.0,29F1.0
     1,3X,24F1.0,5F2.0,F1.0,F1.0/3X,30F1.0,F2.0,23F1.0/3X,17F1.0,9X,8F1.
     20,2X,6F1.0,6X,19X,6F1.0/)
C   LOAD GROUPS ONE AT A TIME
C   FORMAT 2 MUST FIT YOUR DATA CARDS
C   NVAR MUST EQUAL THE NO OF VARIABLES
      XNA=XNA+1.0
      DO 3 J=1,NVAR
      XTOT(J)=XTOT(J)+X(J)
3     STDA(J)=STDA(J)+X(J)**2
      CALL LCARD(NXN)
      GO TO (10,4),NXN
4     WRITE(1,5)
5     FORMAT('RUN OUT CARDS AND LOAD HOPPER WITH SECOND GROUP')
      PAUSE
6     READ(2,2) (X(K),K=1,NVAR)
      XNB=XNB+1.0
      DO 7 J=1,NVAR
      YTOT(J)=YTOT(J)+X(J)
7     STDB(J)= STDB(J)+X(J)**2
      CALL LCARD(NX)
      GO TO (6,9),NX
9     WRITE(3,200) XNA,XNB
200   FORMAT(1H1,4X,  'GROUP(1) N=',F10.0/ 4X,  'GROUP(2) N=', F10.0//
     11X, 'VARIABLE', 5X, 'SUM(1)**2', 4X,'SUM(2)**2', 4X, 'MEAN GR(1)', 4X
     2 4X,'MEAN GR(2)', 4X,'STD GR(1)', 5X, 'STD GR(2)',5X,'T SCORES',/)
      DO 11 K=1,NVAR
      STDAS=SQRT(((XNA*STDA(K)-XTOT(K)**2)/XNA**2)*(XNA/(XNA-1.0)))
      STDBS=SQRT(((XNB*STDB(K)-YTOT(K)**2)/XNB**2)*(XNB/(XNB-1.0)))
      XAV=XTOT(K)/XNA
      YAV=YTOT(K)/XNB
      SIGMA=SQRT((XNA*STDAS**2+XNB*STDBS**2)/(XNA+XNB-2.0))
      TSC=(XAV-YAV)/(SIGMA*SQRT(1.0/XNA+1.0/XNB))
11    WRITE(3,100)K, XTOT(K), YTOT(K), XAV,YAV, STDAS,STDBS,TSC
100   FORMAT(1H , 1X,I4,2X,2(E14.7,2X),2(E14.7,2X),2(E14.7,2X),F14.4)
      WRITE(1,101)
101   FORMAT('IF MORE GROUPS ARE TO BE RUN , RUN OUT CARDS AND LOAD HOPPER
     1ER'/'TURN ON DATA SWITCH 1 AND PUSH START'/'PUSH START TO END PROG
     2RAM WITH DATSW 1 OFF')
      PAUSE
      CALL DATSW(1,LAST)
      GO TO (1000,1001),LAST
1001  CALL EXIT
      END
// XEQ
```

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TITLE

A SURVEY OF THE TEACHING PRACTICES AND MATERIALS USED IN INTRODUCTORY COLLEGE CHEMISTRY — FINAL REPORT.

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RETRIEVAL TERMS

Teaching Practices
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IDENTIFIERS

Teaching Methodology

ABSTRACT

Scope and Method of Study: The survey was conducted to determine the current objectives, teaching methods and teaching materials currently used in teaching introductory college chemistry in accredited institutions of higher education in the continental United States. The materials used in the survey are chiefly (1) a questionnaire and (2) journal periodicals, including Advisory Council on College Chemistry publications.

Findings and Conclusions: The literature review, inclusive in the survey, revealed as many sets of course objectives as there are educators teaching first-year college chemistry; the survey, however, found agreement on six general objectives: (1) to develop the ability to do critical thinking, (2) to make the students familiar with the facts, principles, and concepts of chemistry, (3) to help the student understand the nature of matter and its transformation, (4) to develop the ability to handle quantitative problems, (5) to develop intellectual honesty rather than foster the search for the "right" answer, and (6) to teach students to be precise in observation and expression. With respect to teaching methodology and teaching materials, the following profile is constructed from the survey data: (1) colleges are not using the modern teaching aids and materials recommended by the Advisory Council on College Chemistry, (2) the introductory course is in the midst of a revolution, (3) no one knows the nature of the first year course at this time, (4) there is some emphasis upon cooperation between disciplines, and (5) the evidence is far from conclusive that the professional educators know what they are doing in introductory college chemistry.